Stormwater Capacity Analysis for Strawberry Run, City of Alexandria, Virginia

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Contents

Attachments

Executive Summary

The City of Alexandria, Virginia, has experienced repeated and increasingly frequent flooding events attributable to old infrastructure, inconsistent design criteria, and perhaps climate change. The purpose of the stormwater capacity analysis project is to provide a program for analyzing storm sewer capacity issues, identifying problem areas, developing and prioritizing solutions, and providing support for public outreach and education. The project is being implemented in phases by watershed. The watersheds include Strawberry Run, Four Mile Run, Holmes Run, Cameron Run, Hooffs Run, Backlick Run, Potomac River, and Taylor Run.

This technical memorandum focuses on hydrologic and hydraulic analyses of Strawberry Run watershed using xpswmm. It summarizes the storm sewer system in the Strawberry Run watershed, the model development steps, data sources and gaps, model assumptions, and the results, focusing on the capacity deficiencies identified in the model. These deficiencies will be used as a basis for identifying and prioritizing problem areas during the next phase of the project.

The objective of this phase of the study is to identify the deficient stormwater collection system elements in Strawberry Run during a 10-year return period rainfall event. During the Hooffs Run watershed modeling task, three different design storm scenarios and one historic event were investigated: the City's existing intensity-duration-frequency (IDF) curve, the updated IDF curve using the full record of historical precipitation data (1949 to 2008), the IDF curve projected for the year 2100 using various climate change scenarios, and the June 25–27, 2006 storm event. The results of the Hooffs Run analyses showed that the existing IDF design hyetograph was the most conservative of the design storms (produced the greatest amount of stormwater runoff and flooding), and produced a similar amount of the system flooding to the results from the historic event. Consequently, this scenario was chosen to be used to complete the stormwater capacity analysis for the other watersheds.

The Strawberry Run watershed has a drainage area of 0.54 square miles located in the center of the City, bounded by Cameron Run and Taylor Run. The watershed is drained by Strawberry Run and its tributaries from north to south and discharges in to Cameron Run south of Eisenhower Avenue near Cameron Parke Court. The Strawberry Run storm sewer system model is composed of 489 junctions and 461 segments of storm sewer pipe totaling 6.9 miles.

The hydraulic model predicts that Strawberry Run storm sewer system is experiencing capacity deficiencies in several areas within the watershed. Approximately 16 percent of the analyzed pipes flood the ground surface, 13 percent have a hydraulic grade line within 2 feet of the surface, and 17 percent surcharge above the crown of the pipe. Comparing the peak runoff to the estimated inlet capacity of each catchment indicates that 42 percent of the catchments in the model may have insufficient inlet capacity. Maps and profiles of flooding areas are presented in this technical memorandum to assist in locating problem areas and understanding the capacity deficiencies of the drainage system.

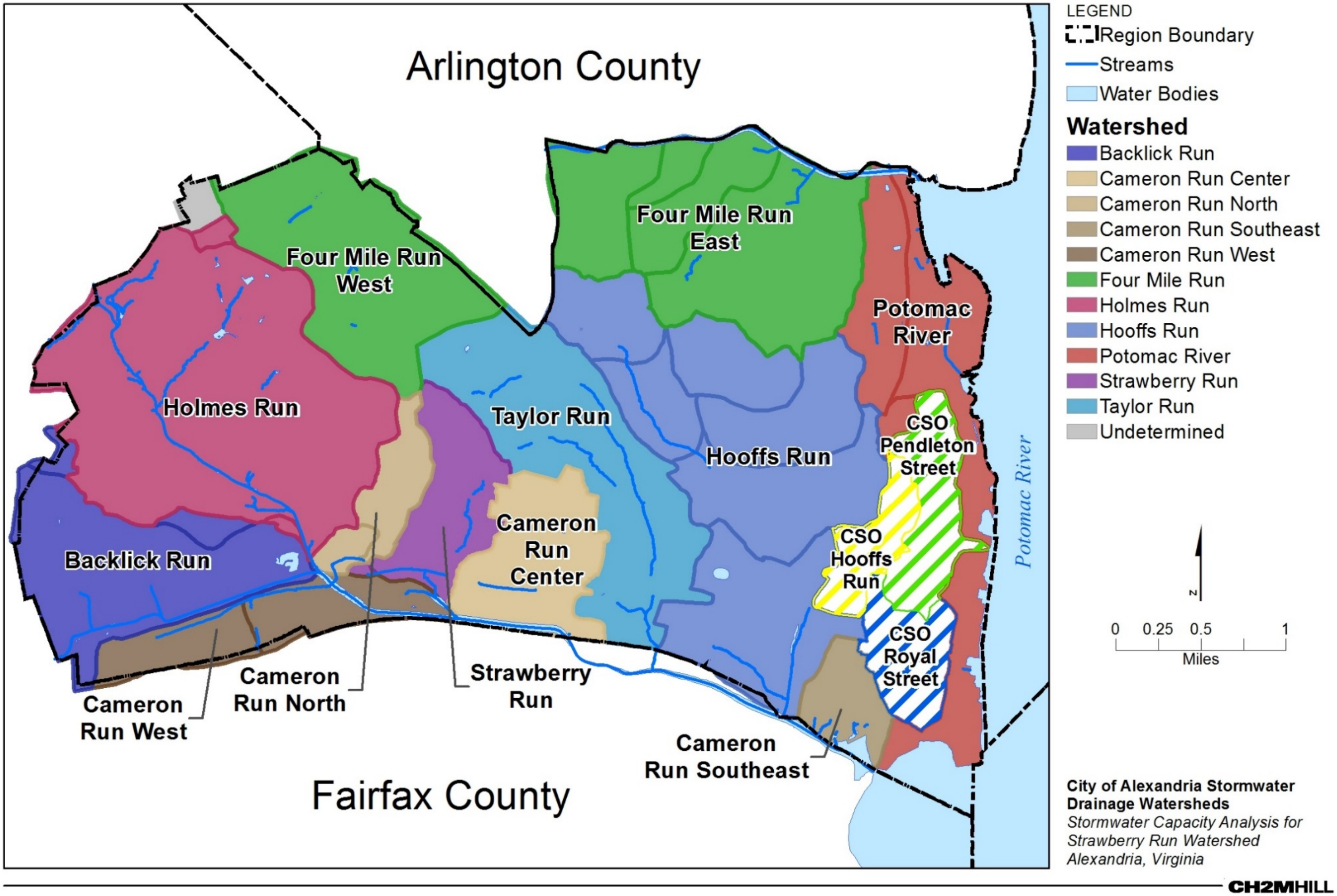
The hydraulic modeling results presented in this memorandum should be reviewed with the understanding that several assumptions were made to fill data gaps, primarily assumptions of inverts in pipes with diameters less than 24 inches.

Project Introduction

The City of Alexandria, Virginia, (City) has experienced repeated and increasingly frequent flooding events attributable to old infrastructure, inconsistent design criteria, and perhaps climate change. The purpose of this project is to provide a program for analyzing storm sewer capacity issues, identifying problem areas, developing and prioritizing solutions, and providing support for public outreach and education. The project is being implemented by watershed. The watersheds include Hooffs Run, Four Mile Run, Holmes Run, Cameron Run, Taylor Run, Strawberry Run, Potomac River, and Backlick Run.

The purpose of this task is to conduct stormwater capacity analysis for the City's existing stormwater collection system within the Strawberry Run watershed. Figure 1 presents the various drainage sewersheds for the City of Alexandria. This technical memorandum describes the methodology and results of the stormwater capacity analysis for the stormwater collection system in the Strawberry Run watershed identified in Figure 1. Additional memorandums describe the results for other watersheds in the City.

FIGURE 1
Stormwater Drainage Watersheds
City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run



Task 2 Objectives

The objective of this phase of the study was to identify the deficient stormwater collection system elements during a 10-year return period storm event. The stormwater collection system elements include the following:

- Closed conduits, such as gravity mains (storm drains) and culverts
- Open channels, such as streams and trapezoidal channels that connect two pipe systems
- Drainage inlets and junctions, such as roadside curb inlets, manholes, catch basins, ponds
- Flow regulating structures, such as weirs, orifices, and tide gates

Description of Existing Stormwater Collection System

The City maintains a geodatabase of all stormwater collection system elements, including conduits and drainage junction points. A checked-out copy of the Strawberry Run geodatabase received from the City on March 21, 2014 was used as the basis of the stormwater collection system model.

Strawberry Run has a drainage area of 0.54 square miles that was subdivided into 109 catchments for modeling purposes. The watershed is located in the center of the City and bounded by the Cameron Run and Taylor Run watersheds. The closed conduit storm sewer system discharges into Strawberry Run, an open channel that drains the watershed from north to south from Fort Williams Parkway to Cameron Run south of Eisenhower Avenue.

The geodatabase was thoroughly reviewed and updated with new survey data, for conduits with diameter 24 inches and larger, collected during Task 3, a Field Survey and Condition Assessment task. In some locations for which survey data were not available, the City's plan and as-built drawings were used to improve data quality and rectify system connectivity. The updated geodatabase was submitted to the City for incorporation (i.e., checked-in) into the City-wide stormwater collection system geodatabase. The updated stormwater collection system in the Strawberry Run watershed contains the following elements:

- 461 pipe segments representing 36,293 linear feet of gravity mains (storm drains). Pipe diameter/width varies from 6 to 113 inches for circular, arched, and elliptical pipes.
- 489 drainage junction points:
  - 2 catch basins
  - 356 drainage inlets
  - 85 manholes
  - 13 nodes (blind connections)
  - 33 pipe inlet/outlets

In addition to the structures represented in the stormwater collection system geodatabase, a network of natural streams and open channels convey storm flows in the City's drainage network. In Strawberry Run, the natural channel network includes the Strawberry Run main stem and a series of smaller open channels and ditches connecting closed conduit storm sewers to the main stem. The Strawberry Run stream centerline is represented separately in the City's geodatabase in a stream feature class. Smaller ditches and stream segments that complete hydraulic connectivity are included in the hydraulic model, but do not exist in the geodatabase.

Public/Private and Disconnected Drainage Systems

The City's geodatabase includes structures that are privately owned. Since the hydraulic analyses and identification of capacity deficiencies include only the public facilities as per direction from the City, the structures located in privately owned parcels were identified and excluded from the model. The methodology that was used to accomplish this is documented in the meeting minutes presented in Attachment A.

Despite survey and review of available drawings and documents, small isolated systems remained in the database. These systems were identified and removed from the model due to lack of accurate information available to connect them to the drainage system. The disconnected systems consisted of only a few structures and did not connect to any larger downstream systems.

Modeled and Analyzed System

After reviewing and updating data in the City's geodatabase, the database was returned to the City and a copy of that geodatabase was used as the starting point for the hydraulic model. At the direction of the City, private and small disconnected systems were removed from the modeled system. The main Strawberry Run stream channel was included in the model north of South Early Street, where the channel re-enters the stormwater system. South of Wheeler Avenue the model terminates at the outfall into the natural channel. Figure 2 shows the stream reaches that were modeled.

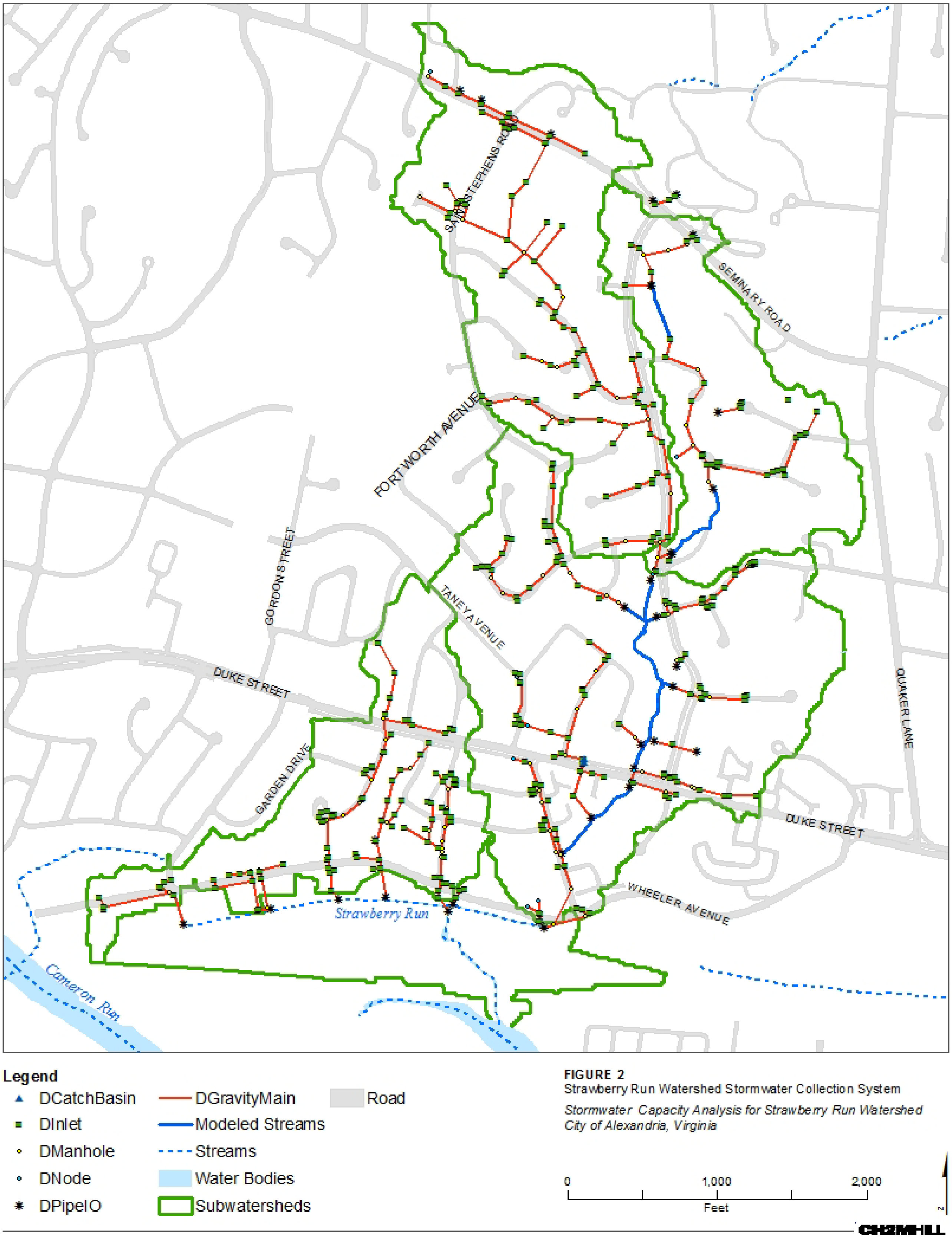
The modeled system only represents an analysis of approximately 20 percent of the inlets as per the scope of work. Since drainage areas were not computed for each inlet in the model, many pipes in the model were upstream of runoff inputs and did not receive any flow. Therefore, 196 pipes with diameter ranging from 6 to 24 inches and 3 pipes with diameter 30 to 48 inches in the upstream-most portions of the system were effectively eliminated from the hydraulic analysis. Only results pertaining to the analyzed system are included in this report. The analyzed system includes the following elements:

- 242 pipe segments representing 25,357 linear feet of gravity mains (storm sewers), or 74% of the total length of storm drains in the geodatabase.[1] Pipe diameter/width varies from 6 to 90 inches[2].
- 260 drainage junction points:
  - 158 drainage inlets
  - 75 manholes
  - 8 nodes (blind connections)
  - 19 pipe inlet/outlets
- 9 open channel segments
- Figure 2 shows a map of the existing stormwater collection system in the Strawberry Run watershed.

[1] Two pipe segments in the City's geodatabase are double barrels represented by a single pipe segment in the model; therefore only 240 unique pipes are analyzed in the model and presented in the results.

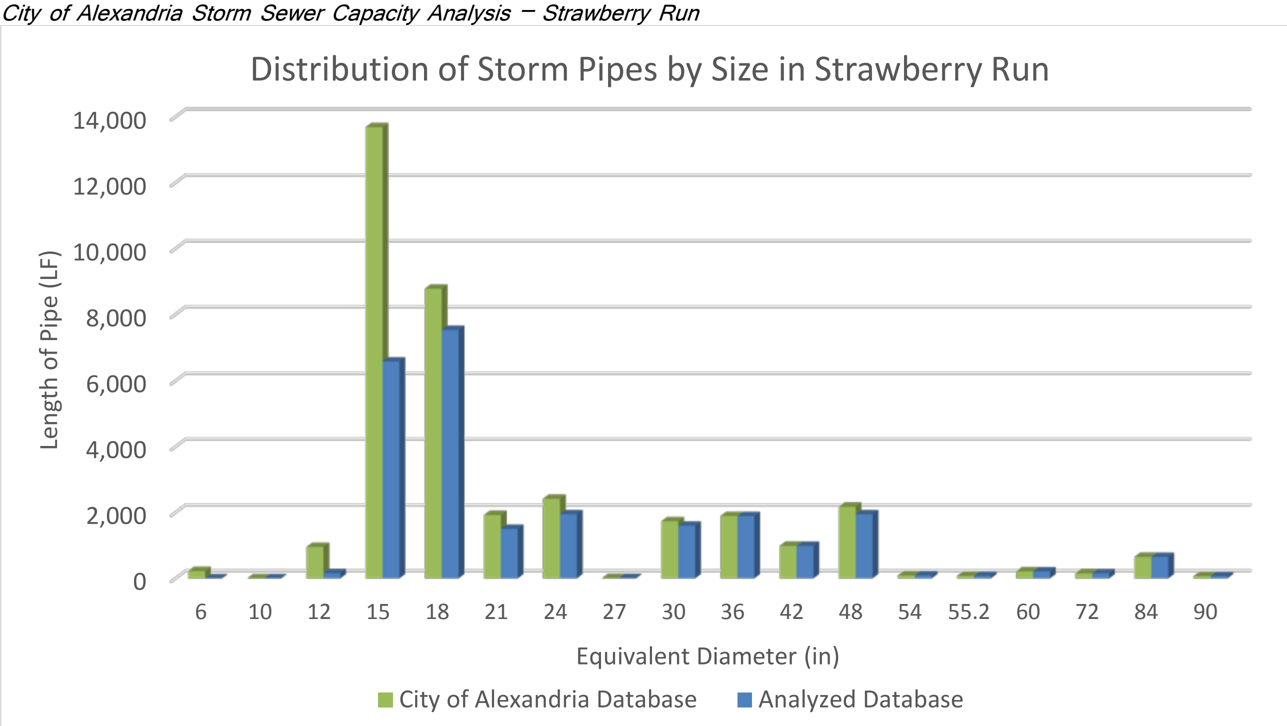
[2] 90 inch pipe is equivalent diameter of elliptical pipe that is 113 inches wide and 72 inches tall

FIGURE 2
Existing Stormwater Collection System, Strawberry Run Watershed
City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run



The distribution by size of storm drains in the City's Strawberry Run geodatabase and the storm drains analyzed in the Strawberry Run model are presented in Figure 3.

FIGURE 3
Distribution of Storm Drains by Size, Strawberry Run Watershed, City of Alexandria, Virginia
City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run



Data Gaps

The available data for the storm drains in the Strawberry Run watershed were evaluated for data quality and completeness. The City's database was updated with data collected from the field survey. However, the field survey included only storm sewer structures connected to pipes with diameter 24 inches or greater (about 40% of the modeled system by length, which does not include private or disconnected structures). Approximately 60% of the modeled system (by length) consists of sewers smaller than 24 inches in diameter and was not surveyed as part of this study. Existing data in the City's most current database were used for modeling the portions of system that were not surveyed.

Some of the structures in the City's most current database are missing data that are critical for modeling storm sewer systems. Examples of data gaps include missing node rim and/or invert elevation and pipe sizes and inverts. A typical missing pipe invert occurs at a location with a blind pipe connection where there is no access manhole, including junction rim and/or invert elevation and pipe size and upstream and/or downstream invert. The data gaps needed to be filled to develop a complete hydraulic model. The following standard approaches were adopted to fill the missing data:

- Missing data were inferred from the available data, if applicable. For example, a missing pipe size was assumed to equal the downstream pipe diameter.
- Pipe diameters at the most-upstream inlets were assumed to be 12 inches.
- A 6-inch-depth to crown was assumed for the most upstream inlets and DNodes.
- Interior point feature invert elevations were estimated by assuming that pipe slope is constant.
- At outfalls and some blind connections to upstream private systems the slope from the next upstream or downstream pipe was used to extrapolate an invert for the outfall or blind connection.

- Limited data available in the GIS for ponds and the outlet control structures were supplemented with data from as-built plans.

In addition to filling in missing data, the data were reviewed for data quality and validity. Assumptions were made when the available data were not reasonable (e.g., a pipe crown was above the rim of a manhole). Additional information regarding the types of assumptions made to complete the hydraulic model are provided in the technical memorandum *Summary of Data Gaps and Assumptions in the Hooffs Run Watershed* (CH2M HILL, 2012), which was provided to the City in October 2012. The same approaches were applied to fill data gaps and resolve unreasonable data in the GIS data for the Strawberry Run watershed, except where field survey data are available.

Modeling Approach

The Strawberry Run watershed was analyzed using commercially available and public domain computer models that are industry accepted and widely used. The public domain software, ArcHydro Tools for ArcGIS 10.0 (version 2.1), was used to aid delineation of catchments and to estimate hydrologic parameters, such as catchment drainage area, slope, and longest flow path. Other hydrologic parameters, such as catchment width and percent impervious, were estimated in ArcGIS after completing the catchment delineation. The private domain software xpswmm (version 2014sp1) was used to simulate rainfall-runoff processes and the performance of the stormwater collection system. The xpswmm software is widely used and industry-accepted commercial stormwater management software. The core simulation engine is based on the USEPA stormwater management model (SWMM) engine.

The City of Alexandria provided the required data listed below:

- Alexandria_Dsewer_CH2MHill_032114.gdb, a copy of the Citywide geodatabase of the stormwater collection system, from which the Strawberry Run database was extracted
- Spring 2011 DVD, City GIS data (geodatabase and orthophotography) such as topographic data and land use

Hydrologic Modeling

The hydrologic modeling required two major types of inputs:

- **Hydrologic parameters:** Delineation of catchments and computation of hydrologic parameters such as drainage area, slope, width, and percent impervious for each catchment.
- **Design Hyetographs** - Development of a 24-hour synthetic rainfall distribution for the 10-year design storm event

Hydrologic Parameters

Hydrologic parameters were estimated using ArcHydro and Hydrologic Engineering Center (HEC)-GeoHMS.

Hydrologic parameters were estimated using ArcHydro. The ArcHydro tools are a set of public domain utilities developed jointly by the Center for Research in Water Resources of the University of Texas at Austin (http://www.crwr.utexas.edu), and the Environmental Systems Research Institute (ESRI). These tools provide functionalities for terrain processing, watershed delineation, and attribute management. They operate on top of the ArcHydro data model in the ArcGIS environment. The model uses a digital elevation model (DEM) of the subject watershed to compute hydrologic parameters. The “burning in” technique allows the user to impose the drainage system on the terrain to better produce the catchment boundaries.

HEC-GeoHMS is geospatial hydrologic modeling software developed and maintained by the HEC of the U.S. Army Corps of Engineers. The model allows users to visualize spatial information, perform spatial analysis, delineate subbasins, and estimate watershed hydrologic parameters. (U.S. Army Corps of Engineers, 2003).

In this study, 2-foot contour data provided by the City were used to create a DEM of the watershed and vicinity. ArcHydro tools were used to delineate the catchments (also referenced as subbasins in the tools) and to compute hydrologic parameters, such as drainage area, slope, and longest flow path for each catchment. Width was derived using the catchment drainage area and longest flow path using the equation, width = (area/longest flow path). Percent impervious was estimated in ArcGIS using the delineated catchments and impervious coverage shapefiles provided by the City.

Updated subwatershed and watershed boundaries were developed using the catchment layer developed during the modeling process and returned to the City. Schematics of the hydrologic model for each subwatershed are presented in Attachment B. The schematics show the catchment ID, delineated boundaries, and longest flow path for each catchment as well as the DEM of the Strawberry Run watershed. The hydrologic parameters for each subwatershed are also presented in Attachment B. The following are the major drainage characteristics for the Strawberry Run watershed, based on the hydrologic model:

- Total drainage area is 0.54 square miles (348 acres)
- Drainage area divided into 4 subwatersheds containing 109 catchments, 100 of which are included in the model[3]
- 32 percent of the drainage area is impervious
- Average catchment area is 3.2 acres
- Average catchment slope is 0.10 feet/feet
- Average catchment width is 181 feet

Design Hyetograph

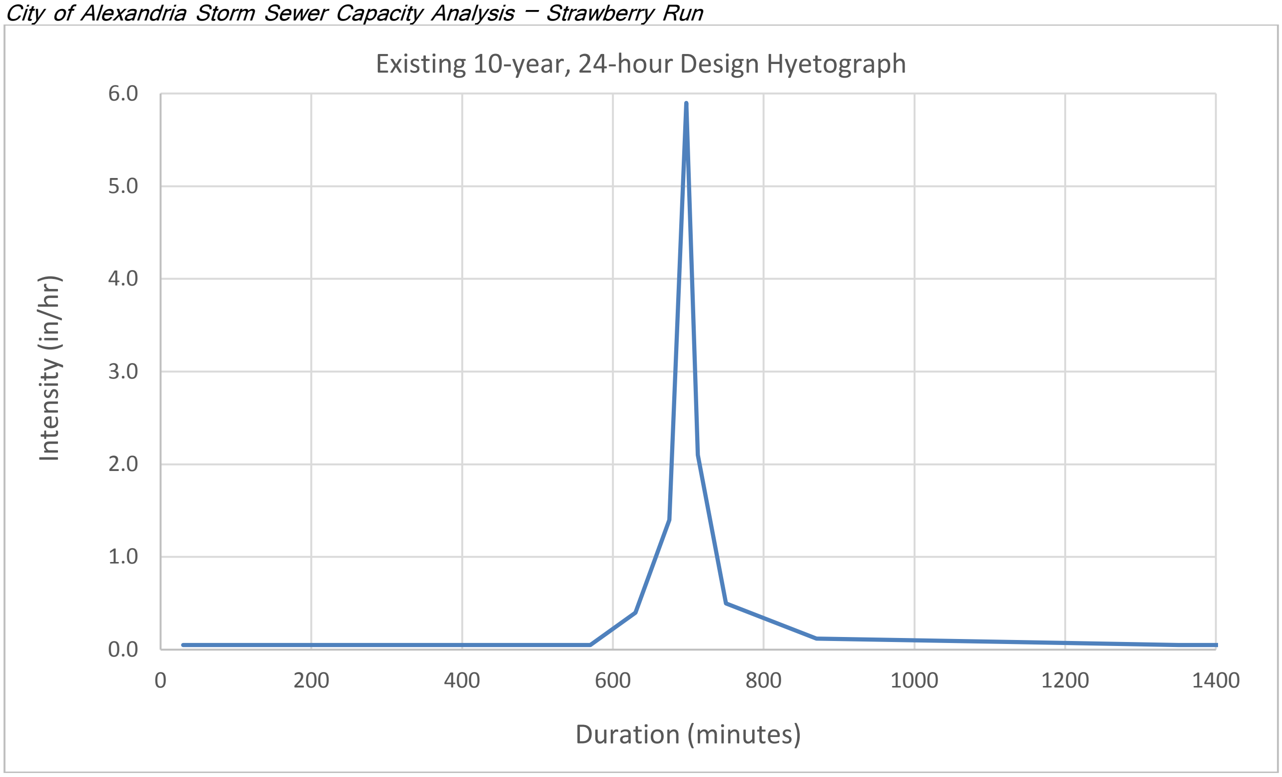
The 24-hour synthetic rainfall distribution for the 10-year design storm event was developed based on rainfall data from the existing intensity-duration-frequency (IDF) curve for the 10-year return period for Alexandria (City of Alexandria, 1989). Time of concentration values were computed for several inlets in the Hooffs Run pilot subwatershed and the Four Mile Run priority subwatershed. Based on these results, the peak rainfall intensity was selected from the IDF curve, based on a 15-minute time of concentration. A variable time interval approach was used to generate the design hyetograph. The design hyetograph was developed to yield maximum rainfall intensity at the approximate center of the 24-hour storm. The 24-hour rainfall total is 5.04 inches, and the peak intensity is 5.9 in./hr. Table 1 and Figure 4 present the existing 10-year, 24-hour design hyetograph.

[3] The xpswmm model includes 100 of the 109 catchments delineated in the Strawberry Run watershed; 9 catchments drain directly to the stream downstream of the model outfall.

TABLE 1
Existing 10-year 24-hour Design Hyetograph Data
City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run

Start Time (minutes)	Duration (minutes)	Absolute Rainfall Depth (inches)	Intensity (in/hr)
0	60	0.05	0.05
60	60	0.05	0.05
120	60	0.05	0.05
180	60	0.05	0.05
240	60	0.05	0.05
300	60	0.05	0.05
360	60	0.05	0.05
420	60	0.05	0.05
480	60	0.05	0.05
540	60	0.05	0.05
600	60	0.40	0.40
660	30	0.70	1.40
690	15	1.475	5.90
705	15	0.525	2.10
720	60	0.50	0.50
780	180	0.36	0.12
960	360	0.48	0.08
1320	60	0.05	0.05
1380	60	0.05	0.05

FIGURE 4
Existing 10-Year 24-Hour Design Hyetograph
City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run



Simulation of Stormwater Runoff

The xpswmm 2014sp1 software was used to simulate rainfall-runoff processes from the Strawberry Run watershed. The hydrologic parameters such as area, slope, width, and percent impervious for the 100 catchments listed in Attachment B were estimated using ArcGIS and ArcHydro Tools, as described in the previous section. These hydrologic parameters and the 10-year, 24-hour design hyetograph were used as input to the RUNOFF module of the xpswmm model. The U.S. Environmental Protection Agency (USEPA) SWMM Runoff Non-linear Reservoir Method was used to simulate the stormwater runoff from each catchment in response to the hyetograph.

Hydraulic Modeling

The xpswmm model was used to simulate the hydraulic performance of the stormwater collection system during a 10-year, 24-hour design storm event. Model input data included the following physical data:

- Junction (inlet, manhole, nodes, etc.) invert and rim elevations
- Closed and open conduit invert elevations, size, shape, material, and length

The data for the stormwater collection system were primarily imported into the model from the geodatabase provided by the City. This geodatabase was updated with survey data for structures that are attached to pipes that are 24 inches or larger in diameter and considered public. Private structures were not modeled, so any private runoff was applied to the next downstream model load point. All elevations (invert and rim) recorded in the geodatabase of the stormwater collection system are in NAVD 88 datum; therefore the xpswmm model was built in NAVD 88.

Entrance or exit loss coefficients were applied to pipes at connections where pipe size significantly increased or decreased. An exit loss coefficient of 0.15 was applied to the smaller (upstream) pipe where the downstream pipe was 2 or more times the size of the upstream pipe or the downstream pipe shape is different. An entrance loss coefficient of 0.1 was applied to the smaller (downstream) pipe where the downstream pipe was half the size, or smaller, of the upstream pipe.

In Strawberry Run, the stormwater collection system includes several large diameter storage pipes, ranging in diameter from 48 to 72 inches. If the structures were installed to provide stormwater detention benefits, an outlet control structure would limit discharge rates to reduce potential flooding downstream. Data were not available on the configuration of these outlet controls, therefore these pipes were included in the model with the entrance and exit losses described above, however outlet controls were not included in this modeling effort. More detailed study of these storage structures is recommended prior to developing or designing stormwater projects near the following pipes:

- 002708STMP, 002709STMP
- 000575STMP
- 003306STMP
- 000935STMP

The Strawberry Run watershed is predominantly drained by the main stem channel of Strawberry Run, which runs from north to south, but also includes several smaller systems that discharge directly to the portion of Strawberry Run that flows west to east parallel to and south of Wheeler Avenue. The hydraulic model developed during this project does not extend beyond the outfalls that discharge into the stream south of Wheeler Avenue, therefore the system was modeled as a series of smaller disconnected systems with 7 separate outfalls.

Of the 7 outfalls, 6 were assigned a free discharge because the drainage area to the outfall is less than 60 percent of the total drainage area to that point on the stream and/or the outfall is located sufficiently above or beyond the peak water surface elevation predicted by the USACE HEC-RAS model for a 10-year storm event. The remaining outfall, which is located just west of the intersection of Wheeler Ave and South

Early Street, has an outfall invert below the 10-year WSE predicted by the USACE HEC-RAS model, therefore it assigned a fixed backwater boundary condition based on the peak USACE 10-year WSE.

In addition to the main stem of Strawberry Run that runs from north to south, there are three smaller open channel reaches (e.g., ditches, open channels connecting pipe systems, etc.) in the Strawberry Run watershed that are included in the model. These short reaches were added to the model as trapezoidal channels to complete the hydraulic connectivity of the closed conduit storm drainage system to the stream near Trinity Drive and Fort Williams Parkway. Channel length, roughness, and slope were estimated using the City's basemap data, including 2-ft contours and aerial photography.

The primary objective of the hydraulic modeling was to analyze pipe capacities. Hydrographs from the RUNOFF module were entered directly into the underground storm sewer system. This approach does not model the flow restrictions caused by the surface inlets and provides a conservative or "worst case" evaluation of pipe capacities. Due to modeling software and data limitations, inlet capacity cannot be readily modeled in xpswmm and is instead being evaluated in a separate spreadsheet. The details of the model limitations encountered during this study and the external spreadsheet evaluation are provided in *Inlet Capacity Analysis for City of Alexandria Storm Sewer Capacity Analysis* (CH2M HILL, 2012).

Model Results

Model results are summarized in the following sections.

Hydrologic Model Results

Peak discharge for each node where overland flow was loaded into the hydraulic model is provided in Attachment C.

Inlet Capacity Results

Inlet capacity was evaluated outside xpswmm due to limitations in the modeling software's capabilities. Details on the evaluation of the options for modeling inlet capacity are provided in *Inlet Capacity Analysis for City of Alexandria Storm Sewer Capacity Analysis* (CH2M HILL, 2012), which was provided to the City in September 2012. The spreadsheet evaluation multiplies the maximum capacity of a single inlet, estimated to be 3.25 cfs based on an assumed standard gutter spread and road cross-section, by the total number of catch basins and inlets draining to a single runoff input point, the location where overland flow was plugged into the hydraulic model. The model has flow loaded into 100 locations with an average of 3.4 inlets per runoff input point. The estimated capacity for each load point was compared to the peak runoff generated in the RUNOFF module of xpswmm to determine whether the catchment has sufficient inlet capacity. Results suggest that about 42 percent of the 100 model load points may be experiencing inlet capacity deficiencies.

The total inlets and catch basins count is based on the City's GIS data for Strawberry Run watershed, including all private and disconnected inlets and catch basins. The City's GIS data does not include all private structures in the Strawberry Run watershed since they are not always included in survey efforts. This effectively underestimates the City's available inlet capacity in this analysis. Inlet capacity results are presented in detail in Attachment C.

Hydraulic Model Results

Model results for the pipes and stream segments are summarized in the following sections. Detailed results are presented in Attachment D.

Pipe Capacity

The conveyance capacity of the existing stormwater collection system during the 10-year, 24-hour storm event was evaluated based on three criteria, listed in order of decreasing severity:

- If the hydraulic grade line (HGL) rose above the ground surface, the structure was considered flooded.

- If the HGL rose to within 2 feet of the ground surface, the structure was considered to have insufficient freeboard.
- If the HGL rose above the crown of the pipe but was more than 2 feet from the ground surface, the structure was considered surcharged.

Pipes were evaluated for these conditions at the upstream end. In some cases the water surface was within 2 feet of the ground surface, but within the pipe (not surcharging), because the crown of the pipe was less than 2 feet from the ground surface. In those cases, the pipes were not included in the "insufficient freeboard" category.

Additional details on the results are presented in the following section. The pipes with flooded, insufficient freeboard and surcharged conditions are summarized in Table 2 and 3. Figure 5 shows the location of pipes experiencing flooding, insufficient freeboard, and surcharged conditions in Strawberry Run watershed. Profiles of pipes displaying conditions of the pipes along the main storm sewer line within the Strawberry Run watershed are provided in Attachment D. The profiles display:

- Vertical cross-sectional view of the conduits, including the inverts and crowns. They also illustrate the flow conditions such as partially full, full, or surcharged.
- Water surface elevation in the conduit (i.e., HGL)
- HGL in junctions such as manholes, inlets, and nodes
- HGL above the conduit crown (surcharged conditions)
- HGL above the ground (flooding)

Note that the profiles presented only show a snapshot of the system during the model simulation. These profiles will not always show the most severe flooding at each location. For example, the profile may not show the flooding symbol at a location even though surface flooding may occur either before or after the snapshot of the profile was taken.

The detailed model results are presented in tabular format in Attachment D. The results presented in this memorandum should be reviewed with the understanding that flow data were not available for model calibration, and several assumptions were made to fill data gaps, primarily, assumptions about pipe inverts where survey data were unavailable.

The model results presented in Table 2 show that 16 percent of the pipes flood the ground surface, 13 percent have a hydraulic grade line within 2 feet of the surface, and 17 percent surcharge above the crown of the pipe. The model predicts flooding and capacity deficiency in the eastern-most storm sewer system of subwatershed 1. This small system has 3 large diameter storage pipes that were modeled without outlet controls, and therefore the model may be over-predicting the flooding problems in this area. A more detailed study of this area and any outlet controls that may be present should be considered prior to moving forward with any projects downstream.

TABLE 2

Watershed Modeling Results, Summarized by Pipe Size

City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run

	Sufficient Capacity			Surcharged			Insufficient Freeboard			Flooded		
Equivalent Pipe Diameter (ft)	Count	Length (LF)	Percent of Total Length	Count	Length (LF)	Percent of Total Length	Count	Length (LF)	Percent of Total Length	Count	Length (LF)	Percent of Total Length
Less than 2.0	65	7,233	29%	30	2,208	9%	25	2,109	8%	32	3,893	16%
2.0 to 2.75	18	2,123	8%	5	662	3%	5	765	3%	0	0	0%
3.0 to 4.9	30	3,033	12%	12	1,439	6%	3	397	2%	2	104	0.4%
5.0 and above	13	1,072	4%	0	0	0%	0	0	0%	0	0	0%
Total	**126**	**13,461**	**54%**	**47**	**4,308**	**17%**	**33**	**3,272**	**13%**	**34**	**3,997**	**16%**

Note: Table does not include pipes upstream of hydrologic load points in the model

Results are based on results at upstream end of pipe

ft = feet

LF = linear feet

TABLE 3

Watershed Model Results, Summary by Capacity

City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run

				Duration (hr)				Volume (ft^3)[a]			
Capacity	Conduit Count	Conduit Length (LF)	Percent of Total Length	Max.	Min.	Avg.	Total	Max.	Min.	Avg.	Total
Sufficient Capacity	126	13,461	54%	-	-	-	-	-	-	-	-
Surcharged[b]	47	4,308	17%	1.2	0.1	0.4	36	-	-	-	-
Insufficient Freeboard	33	3,272	13%	-	-	-	-	-	-	-	-
Flooded	34	3,997	16%	1.2	0.0	0.4	14	13,065	4	2,107	71,650

Notes: All results presented for pipe segments based on capacity at upstream end of pipe.

[a]Flooded volume

[b]Duration of surcharged flow includes time during which conduits have insufficient freeboard or are flooded at the upstream end.

ft^3 = cubic feet

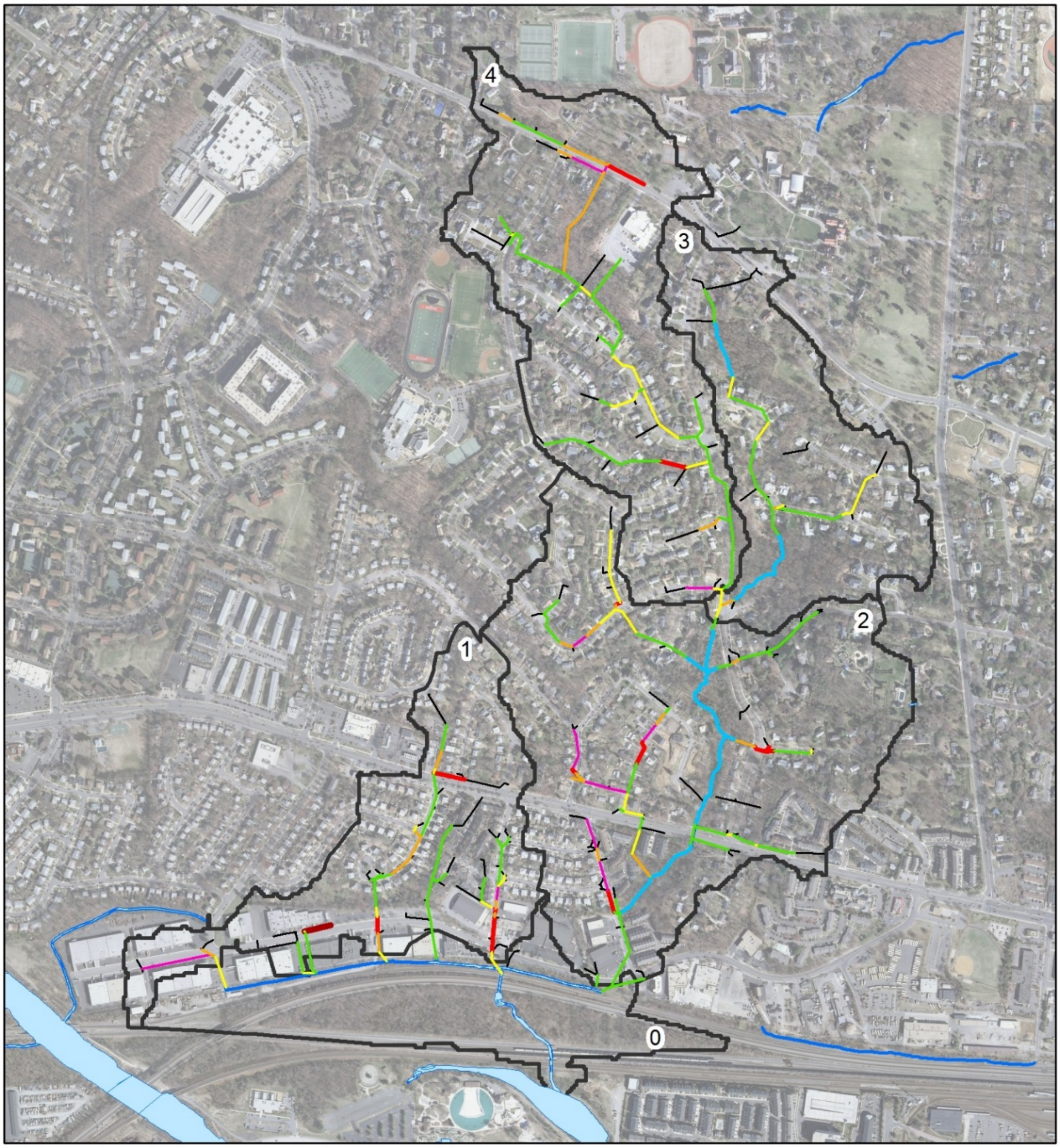
hr = hour

LF = linear feet

FIGURE 5

Strawberry Run Model Results – 10-Year, 24-Hour Based on Existing IDF Curve

City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run



Legend

Model Results
- Sufficient Capacity
- Surcharged
- Insufficient Freeboard

Flood Volume (cu. ft.)
- 0.01 - 1,000
- 1,000 - 10,000
- 10,000 - 15,000
- Not Analyzed (Private, disconnected, upstream of runoff input)

- Modeled Streams
- Water Bodies
- City of Alexandria Streams
- Watersheds

Note: Subwatershed number provided in upper corner of each subwatershed

FIGURE 5

Strawberry Run Watershed Modeling Results

Stormwater Capacity Analysis for Strawberry Run Watershed, City of Alexandria, Virginia

0 500 1,000 2,000

Feet

N

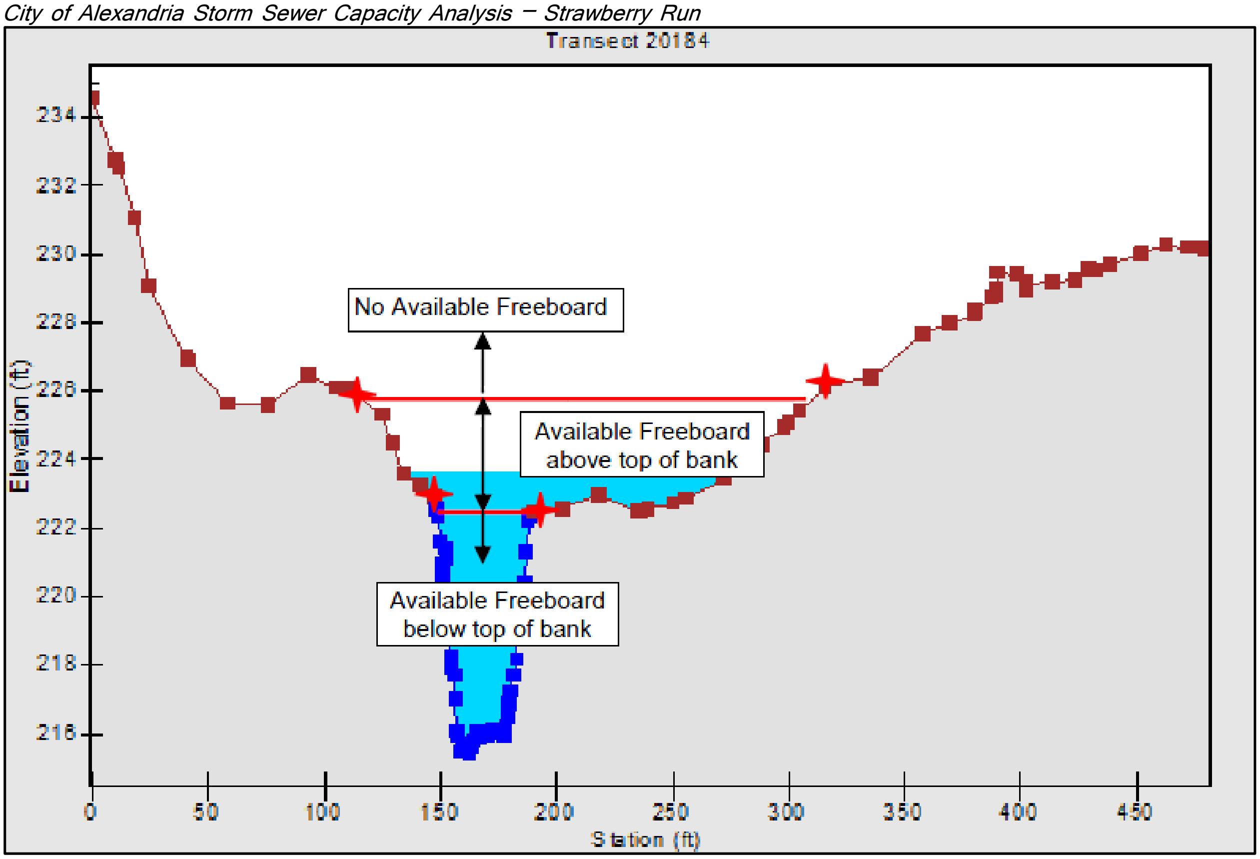
CH2MHILL

Open Channel Results

Water surface levels generated by the model were compared to two points defined on each cross section: top of cross section and top of bank. These points are defined in Figure 6. The conveyance at each cross section was then defined as falling into one of three categories:

- No available freeboard: HGL above the top of cross section
- Available freeboard above top of bank: HGL above the top of bank yet remained below the top of cross section
- Available freeboard below top of bank: HGL below the top of bank

FIGURE 6
Sample Cross Section
City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run



The Strawberry Run hydraulic model contains 39 open channel segments, representing approximately 3,300 LF of open channels:

- 34 natural channel segments (approximately 2,550 LF) from the HEC-RAS model representing the open channel from south of Saylor Avenue near Fort Williams Parkway to south of Wheeler Avenue at South Early Street
- 2 natural channel segments (approximately 380 LF) developed from the DEM representing the open channel parallel to Fort Williams from near Seminary Road to Templeton Place
- 3 trapezoidal channels (approximately 360 LF) connecting the closed conduit system to the Strawberry Run stream channel near the intersection of Fort Williams Parkway and Trinity Drive

While included, open channels were not the focus of this modeling effort, and therefore the capacity of open channels will not be reported in terms other than those described above. Results for stream segments are summarized in Table 4.

TABLE 4
Summary Results for Open Channels
City of Alexandria Storm Sewer Capacity Analysis – Strawberry Run

Scenario	Linear Feet of Stream		
	Available Freeboard Below Top of Bank	**Available Freeboard Above Top of Bank**	**No Available Freeboard**
Existing IDF, existing boundary conditions	1,775	1,517	0

Summary

The hydraulic model predicts that a significant portion, about 46 percent, of the Strawberry Run watershed is experiencing capacity related deficiencies during the 10-year, 24-hour design storm. The model results show that 16 percent of the pipes flood the ground surface, 13 percent have a hydraulic grade line within 2 feet of the surface, and 17 percent surcharge above the crown of the pipe. Comparing the peak runoff to the estimated inlet capacity of each catchment indicates that 42 percent of the catchments in the model may have insufficient inlet capacity. Maps and profiles of flooding areas are presented in Attachment D of this technical memorandum to assist in locating problem areas and understanding the capacity deficiencies of the drainage system.

The hydraulic modeling results presented in this memorandum should be reviewed with the understanding that several assumptions were made to fill data gaps, primarily assumptions of inverts in pipes with diameter less than 24 inches.

References

These documents were consulted in the preparation of this memorandum. Not all are cited in the text.

City of Alexandria. 1989. *Design and Construction Standards*. Department of Transportation & Environmental Services. July.

City of Alexandria. 2011. City of Alexandria GIS data. Spring.

CH2M HILL. 2009a. *Updated Precipitation Frequency Results and Synthesis of New IDF Curves for the City of Alexandria, Virginia.* Prepared for City of Alexandria Transportation & Environmental Services Department. May 1.

CH2M HILL. 2009b. Comparison of Model Hyetograph Generation and Hydrologic Computation Methods. Prepared for City of Alexandria Transportation & Environmental Services Department. July 14.

CH2M HILL. 2009c. *Sea Level Rise Potential for the City of Alexandria, Virginia.* Prepared for City of Alexandria Transportation & Environmental Services Department. June 12.

CH2M HILL. 2011. *Rainfall Frequency and Global Change Model Options for the City of Alexandria*. Prepared for City of Alexandria Transportation & Environmental Services Department. August 30.

CH2M HILL. 2012a. *Inlet Capacity Analysis for City of Alexandria Storm Sewer Capacity Analysis*. Prepared for the City of Alexandria Transportation & Environmental Services Department. September 12.

CH2M HILL. 2012b. *Summary of Data Gaps and Assumptions in the Hooffs Run Watershed,* Prepared for the City of Alexandria Transportation & Environmental Services Department. October 22.

CH2M HILL. 2016. *Stormwater Capacity Analysis for Hooffs Run Watershed, City of Alexandria, Virginia.* Prepared for the City of Alexandria Transportation & Environmental Services Department. February.

U.S. Army Corps of Engineers (USACE). 2003. *User's Manual, Geospatial Hydrologic Modeling Extension HEC-GeoHMS*. Hydrologic Engineering Center, the US Army Corps of Engineers. Version 1.1. December.

Attachment A
Methodology for Identifying Public vs. Private Structures: August 6, 2009, Meeting Summary

City of Alexandria Storm Sewer Capacity Analysis Project – Task Order 1

Meeting, August 6, 2009 (2:30-3:00 pm)

ATTENDEES:

Craig Perl/City of Alexandria
Laurens van der Tak/CH2M HILL
Cheri Salas/ CH2M HILL

FROM: Cheri Salas/CH2M HILL

DATE: August 7, 2009

PROJECT NUMBER: 383412

Meeting Purpose

Review memorandum dated July 31, 2009, entitled Evaluation of modeling issues discussed during July 27, 2009 Progress Meeting

- Discuss results of initial public\private structure determinations
- Review initial evaluation of survey data quality
- Discuss altered approach to filling data gaps associated with missing inlet inverts

Meeting Review

Private vs. Public Structures

It was difficult to readily identify structures as private or public, based solely on the parcel layer because of potential errors in the structure locations. The memorandum includes several examples. Several of these include individual public structures that are upstream of larger private storm sewer areas. Craig will share these with Suzanne and others to confirm a path forward. It was agreed that regardless of the path forward on future sewersheds, we would not change the model for the pilot sewershed, but will not attempt to evaluate capacity limitations in the private areas. Craig will confirm which areas in the memo examples should be evaluated.

As we move into the remainder of Hooffs Run CH2M HILL will identify large areas of private sewers based on a broad visual review of the sewersheds, CH2M HILL will recommend a starting point for the hydraulic model (pour point for hydrologic basin) and allow the City to review the recommendations prior to beginning filling data gaps or modeling.

Stormwater ponds were discussed. These are mostly, if not all, private facilities; however they should have significant impact on the peak flows in the system. It was recognized that there is significant effort associated with obtaining the data for these ponds, and adding it to the model. The one pond in the pilot sewershed was retrofitted since the as-built plans; therefore a site visit may be required to obtain appropriate outlet dimensions.

Survey Data Quality

We do not foresee any significant data issues in the Pilot sewershed related to surveyed inverts; however it may be a bigger issue as we move into flatter sewersheds. This issue will be tabled until we move on to other sewersheds

Filling Data Gaps in Inlet Inverts

As we were filling data gaps we recommended using a 1-foot depth to invert for all inlets for which the data were not available. In approximately 15 of the 153 inlets for which invert data were not available, the pipe diameter was larger than 12-inches, resulting in model errors. A revised approach of using the pipe diameter plus 6-inches as the assumed depth to invert is recommended, however it is unclear whether this approach will be appropriate for the locations in question. CH2M HILL will provide a Google Earth Map of these inlets and Craig will review, and possibly conduct field inspections. CH2M HILL will not continue modeling of the pilot shed until results of this review are received.

Action Items

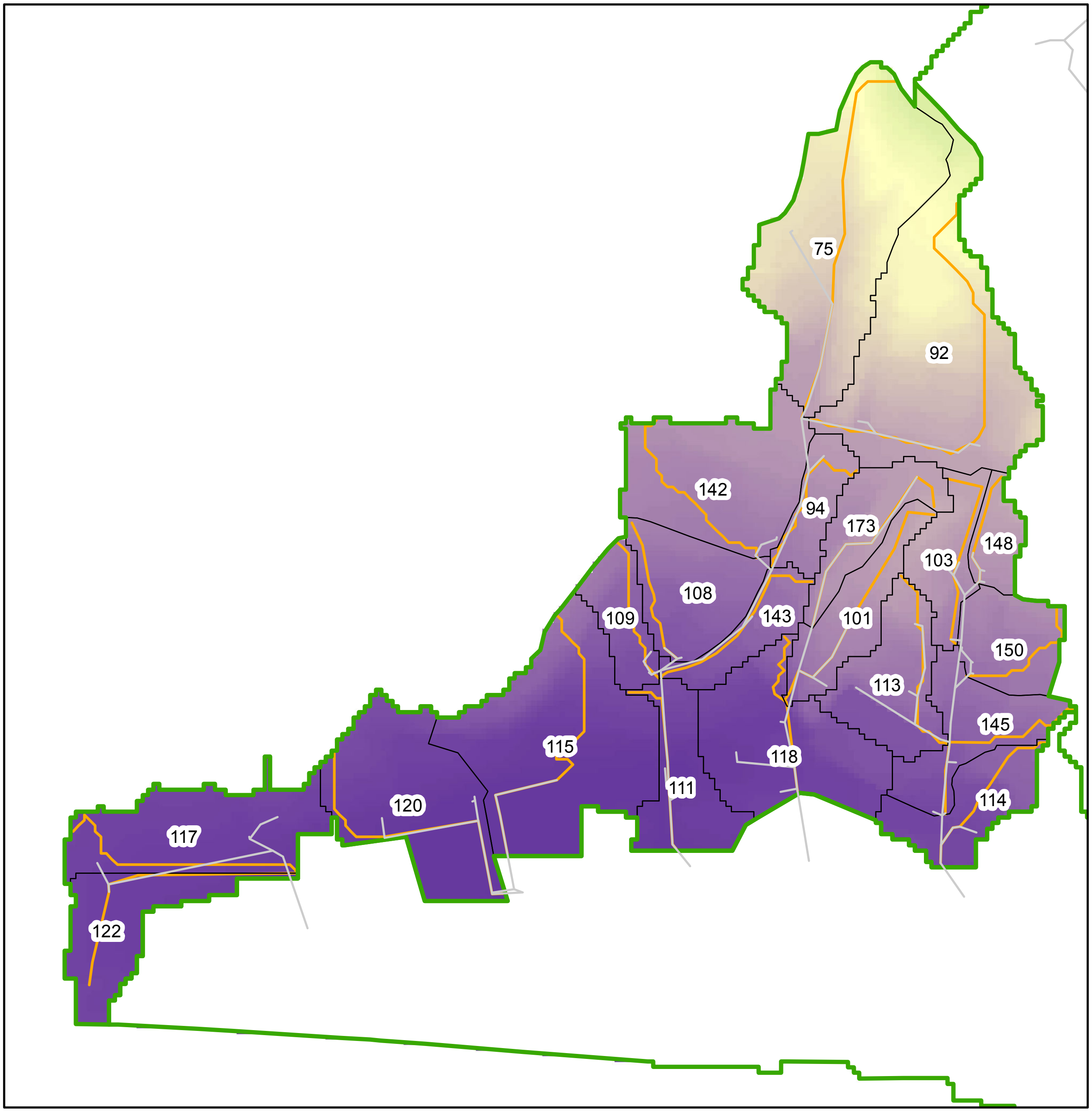
Craig will share July 31, 2009 memo with additional City staff and determine extent of capacity evaluation in pilot area. He will also confirm recommended path forward.

Craig will determine preferred approach to inclusion of stormwater ponds in the model.

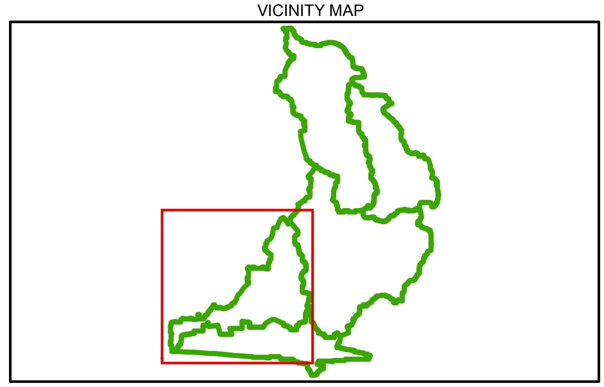
Cheri will provide Google Earth maps of locations where a 1-foot depth to invert was not sufficient.

Craig will review these sites and provide input on an appropriate assumption moving forward.

Attachment B
Hydrologic Model Schematic and Parameters



VICINITY MAP



LEGEND

DEM Elevation (ft)

High : 276

Low : 26

DGravityMain

Longest Flow Path

Modeled Catchments

Subwatersheds

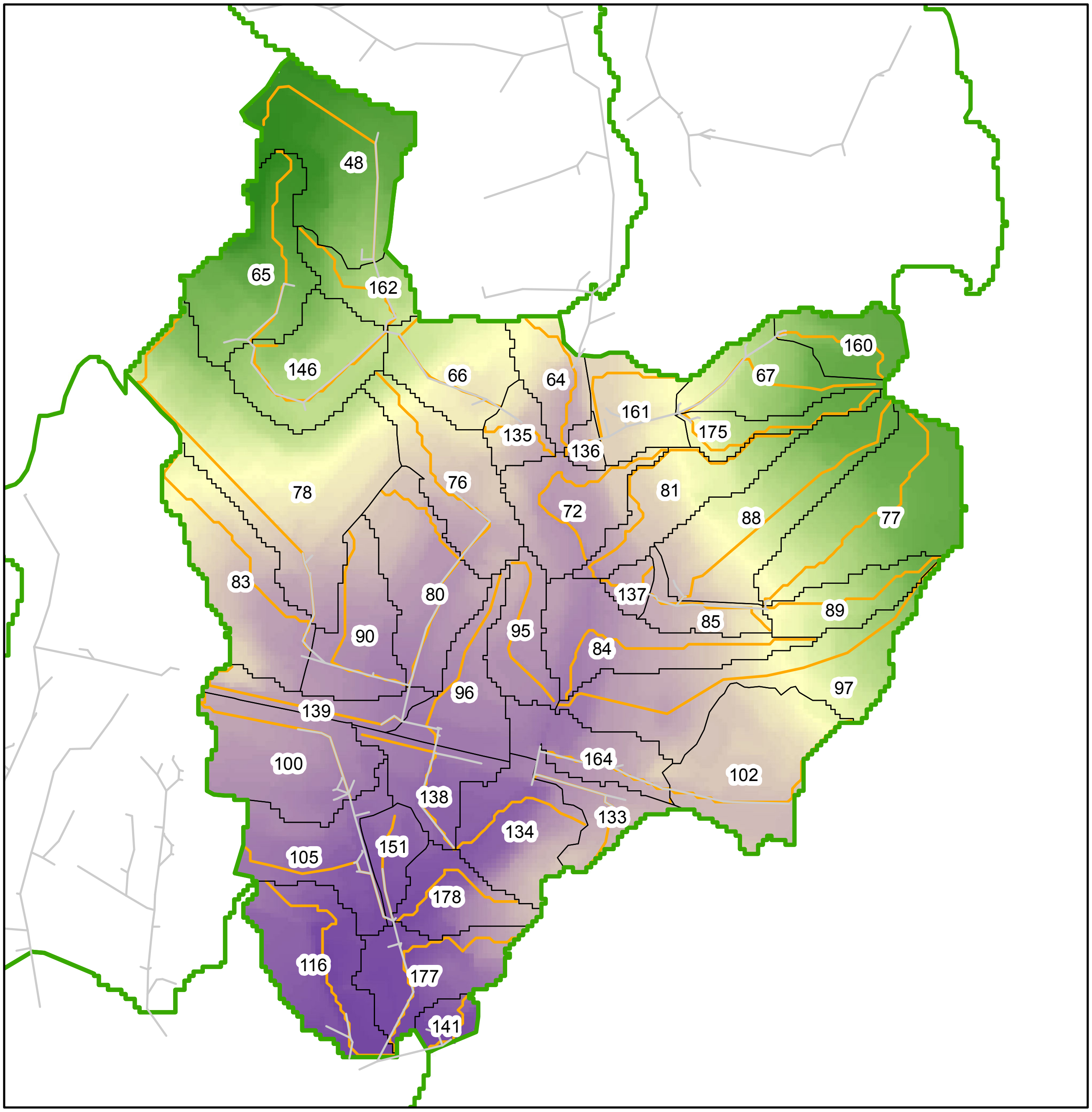
0 500 1,000

Feet

N

FIGURE 1
Strawberry Run Subwatershed 1 Catchments
Stormwater Capacity Analysis for Strawberry Run Watershed, City of Alexandria, Virginia
City of Alexandria Storm Sewer Capacity Analysis

CH2MHILL.



LEGEND

DEM Elevation (ft)

High : 276

Low : 26

DGravityMain

Longest Flow Path

Modeled Catchments

Subwatersheds

0 500 1,000

Feet

VICINITY MAP

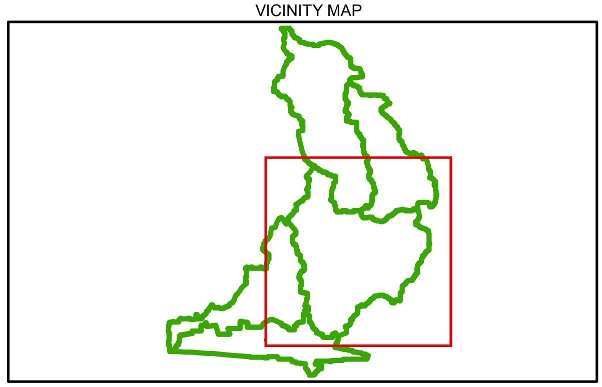


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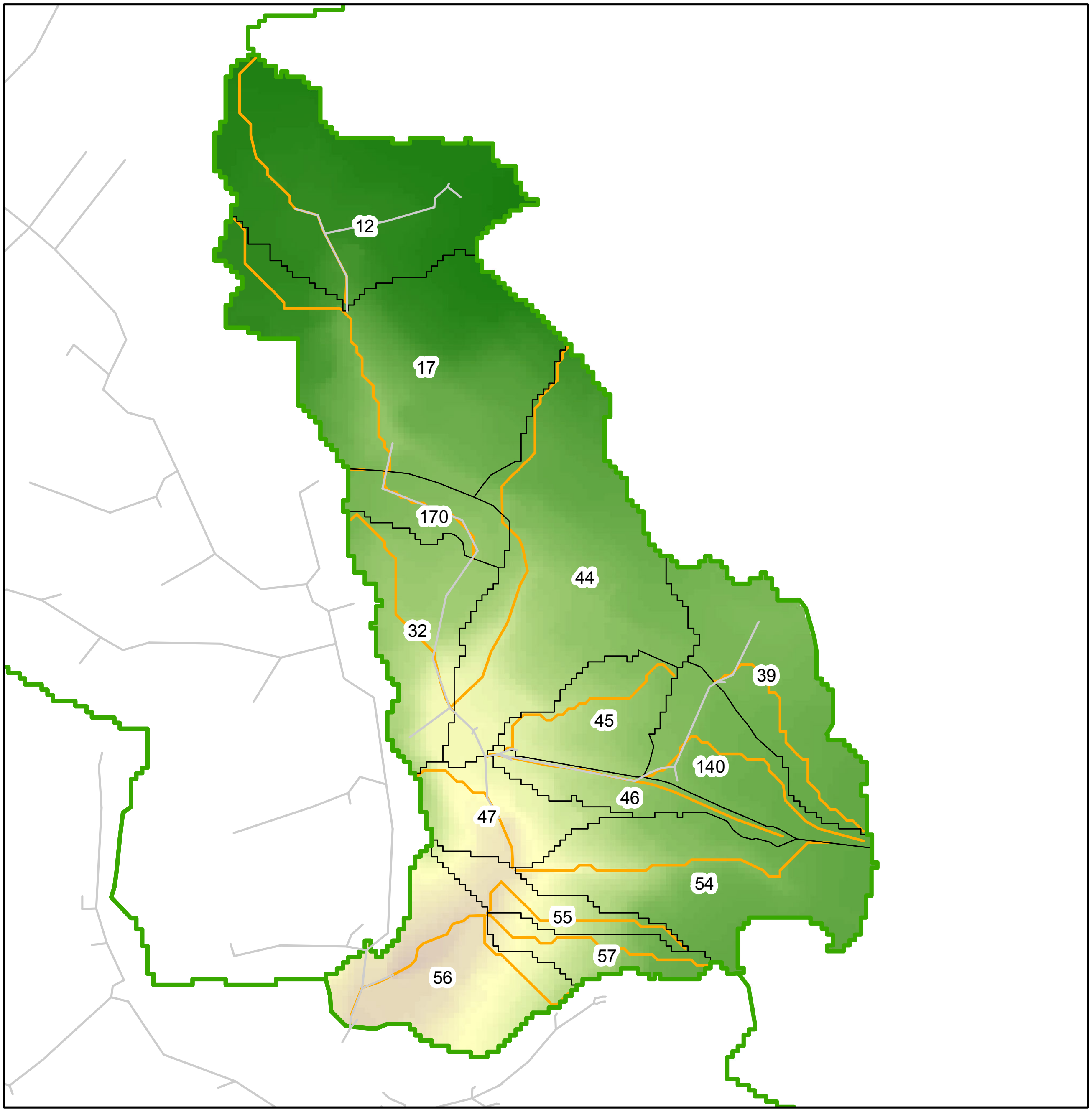
FIGURE 2

Strawberry Run Subwatershed 2 Catchments

Stormwater Capacity Analysis for Strawberry Run Watershed, City of Alexandria, Virginia

City of Alexandria Storm Sewer Capacity Analysis

CH2MHILL



LEGEND

DEM Elevation (ft)

High : 276

Low : 26

DGravityMain

Longest Flow Path

Modeled Catchments

Subwatersheds

0 500 1,000

Feet

N

VICINITY MAP

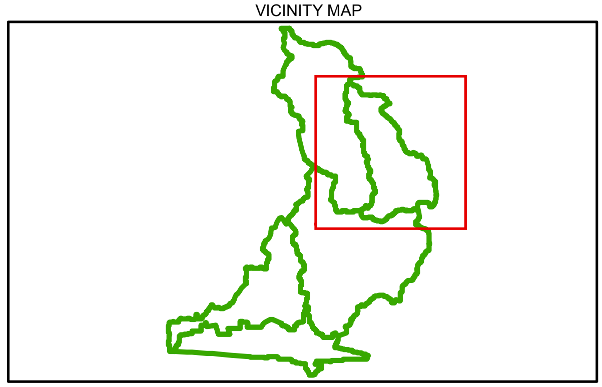


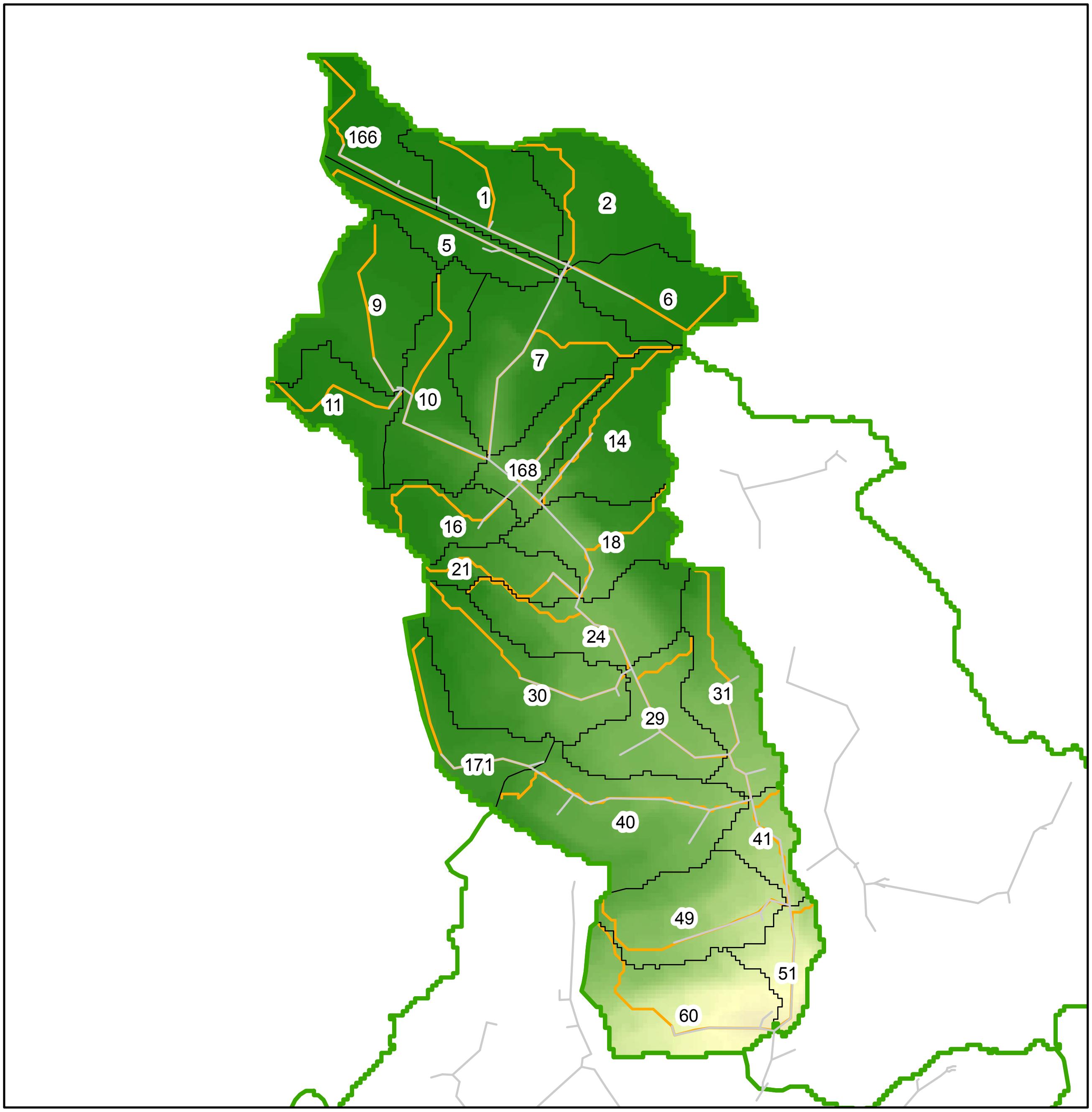
FIGURE 3

Strawberry Run Subwatershed 3 Catchments

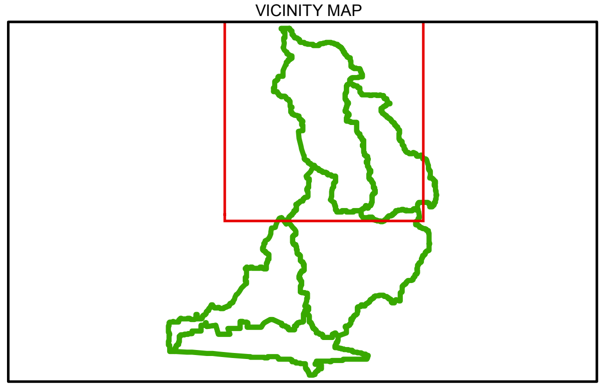
Stormwater Capacity Analysis for Strawberry Run Watershed, City of Alexandria, Virginia

City of Alexandria Storm Sewer Capacity Analysis

CH2MHILL



VICINITY MAP



LEGEND

DEM Elevation (ft)

High : 276

Low : 26

DGravityMain

Longest Flow Path

Modeled Catchments

Subwatersheds

0 500 1,000

Feet

N

FIGURE 4

Strawberry Run Subwatershed 4 Catchments

Stormwater Capacity Analysis for Strawberry Run Watershed, City of Alexandria, Virginia

City of Alexandria Storm Sewer Capacity Analysis

CH2MHILL

Attachment C
Inlet Capacity Results

TABLE 1

Detailed Inlet Capacity Results for Strawberry Run

Sub-shed	Model Load Point	Total Drainage Area (ac)	Total Throat Count	Total Inlet Capacity (cfs)	Peak Runoff (cfs)	Inlet Capacity
1	000614SMH	1.962	3	9.8	10.9	Insufficient
1	000628SMH	1.123	2	6.5	5.7	
1	000630SMH	1.008	3	9.8	4.9	
1	001489IN	6.021	5	16.3	21.6	Insufficient
1	001778IN	0.769	9	29.3	4.0	
1	001783IN	1.323	4	13.0	7.1	
1	001790IN	1.554	6	19.5	7.8	
1	001794IN	1.684	5	16.3	8.7	
1	001799IN	2.128	7	22.8	11.7	
1	001802IN	1.544	5	16.3	7.2	
1	001804IN	6.569	6	19.5	25.2	Insufficient
1	001825IN	3.488	5	16.3	17.8	Insufficient
1	001851IN	5.588	3	9.8	25.0	Insufficient
1	001854IN	3.797	7	22.8	21.4	
1	001866IN	2.147	4	13.0	9.7	
1	001869IN	1.127	5	16.3	5.3	
1	001874IN	3.614	4	13.0	15.9	Insufficient
1	001893IN	1.8	7	22.8	9.6	
1	001894IN	1.685	5	16.3	9.8	
1	002045IN	3.233	6	19.5	18.6	
1	002049IN	2.073	2	6.5	11.1	Insufficient
2	000093IO	0.374	0	0.0	1.9	Insufficient
2	000094IO	1.005	0	0.0	4.5	Insufficient
2	000121IO	0.507	0	0.0	2.3	Insufficient
2	000221ND	8.467	4	13.0	28.5	Insufficient
2	000232ND	2.745	2	6.5	9.5	Insufficient
2	000584SMH	2.943	7	22.8	14.0	
2	000587SMH	4.024	10	32.5	19.1	
2	000588SMH	2.869	2	6.5	15.2	Insufficient
2	000590SMH	0.625	3	9.8	3.6	
2	000591SMH	1.144	3	9.8	5.8	
2	000595SMH	1.458	4	13.0	7.6	
2	000600SMH	2.407	5	16.3	9.3	
2	001261IN	1.728	8	26.0	8.2	
2	001310IN	2.807	3	9.8	12.9	Insufficient
2	001320IN	2.042	5	16.3	9.8	
2	001323IN	1.27	4	13.0	4.8	
2	001331IN	2.556	9	29.3	10.2	
2	001344IN	1.489	4	13.0	7.2	
2	001348IN	5.051	6	19.5	21.0	Insufficient
2	001362IN	3.363	5	16.3	14.6	
2	001367IN	3.946	6	19.5	17.7	
2	001406IN	3.458	3	9.8	12.9	Insufficient
2	001701IN	1.116	2	6.5	6.1	
2	001724IN	3.786	3	9.8	18.7	Insufficient
2	001729IN	1.749	2	6.5	7.6	Insufficient
2	001731IN	5.339	2	6.5	12.5	Insufficient
2	001733IN	4.749	4	13.0	15.3	Insufficient
2	001742IN	2.202	7	22.8	10.1	
2	001752IN	4.454	4	13.0	19.9	Insufficient
2	001757IN	1.412	2	6.5	6.3	
2	001761IN	3.682	4	13.0	13.2	Insufficient
2	001768IN	1.957	4	13.0	8.9	

TABLE 1

Detailed Inlet Capacity Results for Strawberry Run

Sub-shed	Model Load Point	Total Drainage Area (ac)	Total Throat Count	Total Inlet Capacity (cfs)	Peak Runoff (cfs)	Inlet Capacity
2	001771IN	4.104	3	9.8	13.4	Insufficient
2	ND_0.626	1.985	0	0.0	7.4	Insufficient
2	ND_0.693	3.114	0	0.0	12.7	Insufficient
2	ND_0.770	5.098	0	0.0	13.9	Insufficient
2	ND_0.783	1.849	0	0.0	7.6	Insufficient
2	ND_0.829	3.44	0	0.0	9.7	Insufficient
2	ND_0.868	2.774	0	0.0	9.3	Insufficient
2	ND_0.899	2.867	0	0.0	8.5	Insufficient
2	ND_0.977	1.724	0	0.0	6.7	Insufficient
3	000104IO	2.087	0	0.0	8.8	Insufficient
3	000432SMH	1.453	2	6.5	7.0	Insufficient
3	000433SMH	3.369	1	3.3	13.3	Insufficient
3	000896SMH	7.066	6	19.5	25.5	Insufficient
3	001272IN	2.564	5	16.3	9.2	
3	001275IN	1.344	4	13.0	6.1	
3	001281IN	2.243	3	9.8	9.0	
3	001285IN	8.252	4	13.0	23.8	Insufficient
3	001289IN	4.07	4	13.0	12.9	
3	ND_1.073	4.155	1	3.3	14.1	Insufficient
3	ND_1.1175	1.322	0	0.0	4.7	Insufficient
3	ND_1.135	1.281	0	0.0	3.9	Insufficient
3	ND_1.1525	5.261	0	0.0	16.4	Insufficient
3	SRSTR_ND	8.544	1	3.3	25.0	Insufficient
4	000181IO	4.104	0	0.0	10.2	Insufficient
4	000411SMH	4.941	5	16.3	20.2	Insufficient
4	000421SMH	1.689	1	3.3	8.1	Insufficient
4	000886SMH	2.359	0	0.0	9.5	Insufficient
4	000887SMH	3.969	2	6.5	13.9	Insufficient
4	000891SMH	1.976	3	9.8	7.7	
4	000895SMH	5.232	5	16.3	19.3	Insufficient
4	001337IN	4.122	5	16.3	17.2	Insufficient
4	001353IN	5.846	6	19.5	21.1	Insufficient
4	001355IN	2.542	4	13.0	11.3	
4	001390IN	1.519	3	9.8	7.2	
4	001396IN	3.678	7	22.8	16.1	
4	001398IN	3.518	4	13.0	13.2	Insufficient
4	002854IN	2.34	5	16.3	8.4	
4	002856IN	2.704	2	6.5	7.5	Insufficient
4	002859IN	3.371	4	13.0	8.6	
4	002862IN	3.38	1	3.3	12.2	Insufficient
4	002865IN	5.734	4	13.0	15.3	Insufficient
4	002868IN	2.373	2	6.5	10.2	Insufficient
4	002871IN	3.068	2	6.5	11.7	Insufficient
4	002873IN	1.725	2	6.5	7.2	Insufficient
4	002876IN	3.998	3	9.8	15.1	Insufficient
4	002888IN	4.764	2	6.5	13.3	Insufficient
4	002889IN	3.915	1	3.3	15.4	Insufficient

Attachment D
Detailed Model Results

TABLE 1

Strawberry Run Hydraulic Model Detailed Results

		Junction FaciltiyID						Duration of Surcharge (hrs)		Surcharge/ Depth Above Crown (ft)		Insufficient Freeboard/ Depth Below Rim (ft)		Duration of Flooding (hrs)		Flooded Volume (ft3)		
Subshed	DGravityMain FacilityID	US	DS	Length (ft)	Diameter/ Height x Width (ft)	Maximum Flow (ft3/s)	Maximum Velocity (fps)	US	DS	US	DS	US	DS	US	DS	US	DS	Summary Pipe Condition
1	000576STMP	001783IN	000605SMH	61.214	1.25	7.03	7.19	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	000580STMP	000605SMH	000606SMH	122.834	1.25	10.99	14.46	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	000582STMP	000606SMH	000610SMH	128.988	1.25	10.93	12.81	0	0.1	-	Flooded	-	Flooded	0	0.03833333	0	18.03	Sufficient Capacity
1	000781STMP	001489IN	001490IN	171.725	1.5	21.58	16.07	0	0	-	0.373	-	1.427	0	0	0	0	Sufficient Capacity
1	000933STMP	001894IN	001904IN	48.866	1.5	32.08	18.03	0.6	0.1	2.019	0.425	-	-	0	0	0	0	Surcharged
1	000934STMP	000609SMH	001811IN	76.097	1.25	11.68	15.45	0	0	-	0.819	-	-	0	0	0	0	Sufficient Capacity
1	000937STMP	001824IN	001825IN	123.741	1.75	15.78	11.22	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	000938STMP	001825IN	001826IN	58.79	2.5	33.11	8.92	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	000940STMP	001826IN	000130IO	197.029	2.5	33.23	8.01	0	0	-	-	-	1.34	0	0	0	0	Sufficient Capacity
1	002034STMP	000616SMH	001832IN	32.796	3	-79.62	11.2	0.5	0.4	Flooded	2.082	Flooded	1.318	0.23666667	0	1069.91	0	Flooded
1	002035STMP	001832IN	001834IN	118.814	3	79.62	11.22	0.4	0.4	2.082	0.901	1.318	-	0	0	0	0	Insufficient Freeboard
1	002065STMP	000623SMH	001852IN	9.989	1.25	10.36	8.57	1.2	0	0.336	-	-	-	0	0	0	0	Surcharged
1	002066STMP	001853IN	000624SMH	201.321	2	10.36	5.38	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002067STMP	001854IN	001855IN	201.797	2.5	21	5.29	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002070STMP	001855IN	000133IO	82.778	2.5	-21.02	4.44	0	0	0.109	-	-	-	0	0	0	0	Surcharged
1	002072STMP	000624SMH	000133IO	24.7	2	-10.36	4.65	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002077STMP	000640SMH	000631SMH	144.754	2	39.3	15.29	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002176STMP	001904IN	000135IO	110.971	1.5	31.81	19.11	0.1	0	0.625	-	-	0.62	0	0	0	0	Surcharged
1	002773STMP	001813IN	000612SMH	25.696	1.25	9.78	9.96	0.4	0.5	Flooded	Flooded	Flooded	Flooded	0.3	0.4	870.57	2537.27	Flooded
1	002774STMP	001811IN	001813IN	80.058	1.25	9.43	7.59	0	0.4	2.419	Flooded	-	Flooded	0	0.3	0	870.57	Surcharged
1	002775STMP	000613SMH	000614SMH	28.246	1.5	20.04	11.02	0.5	0.5	8.736	Flooded	0.464	Flooded	0	0.43333333	0	1778.37	Insufficient Freeboard
1	002776STMP	000614SMH	000615SMH	144.054	1.5	26.75	14.63	0.5	0.6	Flooded	Flooded	Flooded	Flooded	0.43333333	0.54166667	1778.37	3875.55	Flooded
1	002778STMP	000615SMH	001894IN	80.399	1.5	26.14	14.54	0.6	0.6	Flooded	2.019	Flooded	-	0.54166667	0	3875.55	0	Flooded
1	002785STMP	001834IN	000134IO	74.873	3	-79.62	11.29	0.4	0	0.901	-	-	0.235	0	0	0	0	Surcharged
1	002974STMP	001847IN	000616SMH	71.578	3	82.13	11.54	0.5	0.5	Flooded	Flooded	Flooded	Flooded	0.22	0.23666667	1626.66	1069.91	Flooded
1	002976STMP	001895IN	000640SMH	36.479	1.5	21.29	12.02	0	0	0.481	-	-	-	0	0	0	0	Surcharged
1	002977STMP	001490IN	001895IN	111.981	1.5	21.23	12.91	0	0	0.573	0.181	1.427	-	0	0	0	0	Insufficient Freeboard
1	002980STMP	001866IN	000626SMH	55.121	1.25	9.72	11.14	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002981STMP	000626SMH	001893IN	186.478	2.5	78.16	17.83	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002982STMP	000627SMH	000626SMH	117.134	2.5	64.13	16.18	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002983STMP	001869IN	000626SMH	26.307	1.25	5.3	10	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	002987STMP	000628SMH	000627SMH	139.762	2	64.12	20.33	0.1	0	2.536	-	1.864	-	0	0	0	0	Insufficient Freeboard
1	002988STMP	000629SMH	000628SMH	171.218	2	58.74	20.42	0.1	0.1	2.942	2.536	0.558	1.864	0	0	0	0	Insufficient Freeboard
1	002991STMP	000630SMH	000629SMH	183.403	2	43.88	19.16	0	0.1	-	2.442	-	0.558	0	0	0	0	Sufficient Capacity
1	002992STMP	001873IN	000629SMH	60.363	1.5	15.37	11.25	0.1	0.1	1.913	2.442	1.887	0.558	0	0	0	0	Insufficient Freeboard
1	002993STMP	001874IN	001873IN	32.883	1.5	15.68	15.28	0	0.1	0.248	1.613	-	1.887	0	0	0	0	Surcharged
1	002996STMP	000631SMH	000630SMH	102.912	2	39.26	19.5	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003300STMP	001775IN	000605SMH	55.953	1.25	3.99	8.4	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003301STMP	001778IN	001775IN	30.952	1.25	3.99	11.97	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003303STMP	001790IN	001792IN	30.991	1.25	7.44	11.22	0	0	1.121	2.33	-	-	0	0	0	0	Surcharged
1	003305STMP	001792IN	000610SMH	57.763	1.25	7.5	7.71	0	0.1	2.43	Flooded	-	Flooded	0	0.03833333	0	18.03	Surcharged
1	003306STMP	001799IN	000609SMH	79.243	6	11.73	4.05	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003308STMP	001794IN	000607SMH	76.008	1.25	8.7	15.31	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003309STMP	001802IN	001795IN	91.282	1.25	7.17	7.28	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003310STMP	001795IN	001796IN	138.536	1.25	7.16	12.16	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003311STMP	001796IN	001797IN	139.613	1.25	7.16	14.89	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003312STMP	000607SMH	001797IN	41.523	1.25	8.7	16.96	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003314STMP	001797IN	001824IN	144.658	1.75	15.75	19.46	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity

TABLE 1

Strawberry Run Hydraulic Model Detailed Results

		Junction FaciltiyID						Duration of Surcharge (hrs)		Surcharge/ Depth Above Crown (ft)		Insufficient Freeboard/ Depth Below Rim (ft)		Duration of Flooding (hrs)		Flooded Volume (ft3)		
Subshed	**DGravityMain FacilityID**	**US**	**DS**	**Length (ft)**	**Diameter/ Height x Width (ft)**	**Maximum Flow (ft3/s)**	**Maximum Velocity (fps)**	**US**	**DS**	**US**	**DS**	**US**	**DS**	**US**	**DS**	**US**	**DS**	**Summary Pipe Condition**
1	003319STMP	001804IN	000640SMH	204.831	1.5	18.12	10.14	0.5	0	Flooded	-	Flooded	-	0.36833333	0	1167.42	0	Flooded
1	003325STMP	000610SMH	000611SMH	94.763	1.25	17.76	14.76	0.1	0.3	Flooded	2.212	Flooded	0.338	0.03833333	0	18.03	0	Flooded
1	003326STMP	000611SMH	000612SMH	51.906	1.25	17.75	14.36	0.3	0.5	2.262	Flooded	0.338	Flooded	0	0.4	0	2537.27	Insufficient Freeboard
1	003327STMP	000612SMH	000613SMH	26.759	1.25	20.04	16.08	0.5	0.5	Flooded	1.786	Flooded	0.464	0.4	0	2537.27	0	Flooded
1	003351STMP	001851IN	000623SMH	172.03	1.25	10.36	8.29	1.2	1.2	Flooded	0.286	Flooded	-	1.17333333	0	13064.53	0	Flooded
1	003352STMP	001852IN	001853IN	48.098	1.75	10.36	7.53	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
1	003416STMP	000679SMH	002125IN	31.934	2	27.9	8.84	0.1	0.1	0.707	0.508	1.793	-	0	0	0	0	Insufficient Freeboard
1	003417STMP	002045IN	000679SMH	69.002	1.75	17.77	7.36	0	0.1	0.923	0.957	1.327	1.793	0	0	0	0	Insufficient Freeboard
1	003419STMP	002125IN	000610IO	204.75	2	27.8	8.87	0.1	0	0.708	-	-	-	0	0	0	0	Surcharged
1	003422STMP	002049IN	000679SMH	451.592	1.5	10.55	5.92	0.2	0.1	Flooded	1.207	Flooded	1.793	0.07166667	0	68.44	0	Flooded
1	014708STMP	001893IN	001847IN	60.997	3	87.28	12.25	0	0.5	3.985	Flooded	-	Flooded	0	0.22	0	1626.66	Surcharged
2	000442STMP	000424SMH	001310IN	95.627	1.5	33.3	18.59	0.6	0	3.536	-	-	-	0	0	0	0	Surcharged
2	000443STMP	001362IN	000425SMH	119.055	1.5	18.5	10.35	0.8	0.8	7.035	6.871	0.815	-	0	0	0	0	Insufficient Freeboard
2	000444STMP	001363IN	001362IN	112.127	1.5	15.67	10.18	0.8	0.8	Flooded	6.935	Flooded	0.815	0.175	0	460.68	0	Flooded
2	000446STMP	000427SMH	001363IN	96.459	1.5	17.66	9.81	0.3	0.8	4.552	Flooded	1.648	Flooded	0	0.175	0	460.68	Insufficient Freeboard
2	000449STMP	001367IN	001369IN	130.575	1.25	17.62	16.89	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	000450STMP	001368IN	000426SMH	53.138	1.5	17.65	14.32	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	000451STMP	001369IN	001368IN	34.721	1.5	17.63	11.81	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	000453STMP	000426SMH	000427SMH	129.573	1.5	17.66	16.01	0	0.3	-	2.352	-	1.648	0	0	0	0	Sufficient Capacity
2	000568STMP	000118IO	000582SMH	12.785	7	622.69	17.15	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	000884STMP	000434SMH	001404IN	149.674	1.25	12.3	9.89	0.3	0.9	Flooded	Flooded	Flooded	Flooded	0.05833333	0.44833333	24.48	1123.2	Flooded
2	000885STMP	001405IN	000434SMH	98.186	1.25	12.57	11.67	0.1	0.3	1.712	Flooded	1.438	Flooded	0	0.05833333	0	24.48	Insufficient Freeboard
2	002202STMP	000211ND	000092IO	41.431	6	366.03	17.62	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002208STMP	001320IN	000416SMH	68.639	1.5	30.84	17.27	0.2	0	2.787	-	1.363	-	0	0	0	0	Insufficient Freeboard
2	002209STMP	001326IN	001320IN	176.039	1.5	23.11	18.65	0	0.2	-	2.737	-	1.363	0	0	0	0	Sufficient Capacity
2	002210STMP	000416SMH	000417SMH	34.295	1.75	30.85	27.49	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002212STMP	000417SMH	000093IO	47.669	1.75	30.85	20.78	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002214STMP	001323IN	001326IN	43.365	1.25	4.76	13.56	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002218STMP	001330IN	001326IN	81.538	1.25	18.35	19.25	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002221STMP	001331IN	001330IN	101.91	1.25	18.34	19.49	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002222STMP	001332IN	001331IN	113.499	1.25	8.23	15.02	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002224STMP	000418SMH	001332IN	97.404	1.25	8.24	17.05	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002265A	000582SMH	000169ND	90.911	7	651.29	19.01	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002265B	000169ND	000588SMH	154.375	7	651.46	18.59	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002266STMP	000583SMH	000582SMH	35.458	1.5	24.1	15.8	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002267STMP	000584SMH	000583SMH	146.52	1.5	24.1	13.4	0.5	0	Flooded	-	Flooded	-	0.375	0	3446.1	0	Flooded
2	002282STMP	001701IN	000582SMH	102.892	1.25	6.08	11.11	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002428STMP	001303IN	001304IN	33.79	1.5	17.96	9.99	0.6	0.6	Flooded	3.998	Flooded	1.252	0.57166667	0	6560.92	0	Flooded
2	002429STMP	001344IN	001303IN	110.79	1.5	26.75	16.52	0.1	0.6	1.313	Flooded	-	Flooded	0	0.57166667	0	6560.92	Surcharged
2	002430STMP	001304IN	001305IN	31.159	1.5	17.98	13.96	0.6	0.6	3.998	4.781	1.252	-	0	0	0	0	Insufficient Freeboard
2	002431STMP	001305IN	001306IN	48.026	1.5	33.3	18.39	0.6	0.6	6.031	4.244	-	-	0	0	0	0	Surcharged
2	002432STMP	000425SMH	001305IN	130.835	1.5	18.97	10.64	0.8	0.6	6.921	5.781	-	-	0	0	0	0	Surcharged
2	002435STMP	000410SMH	000419SMH	91.959	2	45.97	17.87	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002437STMP	001310IN	000410SMH	206.01	1.75	45.96	23.03	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002442STMP	001261IN	000418SMH	27.161	1.25	8.25	15.47	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002443STMP	001306IN	000424SMH	76.761	1.5	33.3	18.38	0.6	0.6	6.194	3.536	-	-	0	0	0	0	Surcharged
2	002444STMP	000419SMH	000094IO	47.241	2.5	45.99	14.39	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002456STMP	001345IN	001344IN	97.114	1.25	19.96	18.07	0	0.1	1.15	0.963	-	-	0	0	0	0	Surcharged

TABLE 1

Strawberry Run Hydraulic Model Detailed Results

Subshed	DGravityMain FacilityID	Junction FaciltiyID		Length (ft)	Diameter/ Height x Width (ft)	Maximum Flow (ft3/s)	Maximum Velocity (fps)	Duration of Surcharge (hrs)		Surcharge/ Depth Above Crown (ft)		Insufficient Freeboard/ Depth Below Rim (ft)		Duration of Flooding (hrs)		Flooded Volume (ft3)		Summary Pipe Condition
		US	DS					US	DS	US	DS	US	DS	US	DS	US	DS	
2	002457STMP	001348IN	001345IN	271.29	1.25	20.51	17.76	0	0	1.414	0.05	-	-	0	0	0	0	Surcharged
2	002478STMP	001404IN	001762IN	8.255	1.25	-10.67	8.61	0.9	0.9	Flooded	Flooded	Flooded	Flooded	0.44833333	0.54666667	1123.2	1606.42	Flooded
2	002479STMP	001406IN	001405IN	35.619	1.25	12.57	15.32	0	0.1	-	1.512	-	1.438	0	0	0	0	Sufficient Capacity
2	002481B	000221ND	001410IN	44.454	1	16.17	19.61	1	0.6	Flooded	Flooded	Flooded	Flooded	0.74333333	0.58	62.84	640.19	Flooded
2	002684STMP	000591SMH	001737IN	53.64	1.5	21.88	12.13	1.1	1	Flooded	Flooded	Flooded	Flooded	0.34333333	0.97666667	1393.96	8733.13	Flooded
2	002686STMP	001733IN	001737IN	37.682	1.25	10.35	9.04	0.9	1	Flooded	Flooded	Flooded	Flooded	0.79666667	0.97666667	2923.11	8733.13	Flooded
2	002690STMP	001737IN	000592SMH	63.401	1.5	22.34	12.41	1	1.1	Flooded	Flooded	Flooded	Flooded	0.97666667	0.96666667	8733.13	2812.93	Flooded
2	002691STMP	000592SMH	001738IN	14.831	1.5	20.9	13.63	1.1	1.1	Flooded	3.509	Flooded	0.791	0.96666667	0	2812.93	0	Flooded
2	002692STMP	001738IN	000121IO	127.45	1.5	20.9	11.62	1.1	0	4.509	-	0.791	-	0	0	0	0	Insufficient Freeboard
2	002693STMP	001768IN	000122IO	186.94	3	65.12	9.26	0.4	0	1.835	-	0.865	-	0	0	0	0	Insufficient Freeboard
2	002697STMP	001742IN	000594SMH	46.937	1.5	28.39	16.99	0	0	0.123	-	-	-	0	0	0	0	Surcharged
2	002699STMP	001744IN	001742IN	55.121	1.5	18.8	15.25	0	0	-	0.123	-	-	0	0	0	0	Sufficient Capacity
2	002702STMP	000594SMH	000599SMH	144.296	1.5	28.37	22.51	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002706STMP	000596SMH	001744IN	103.277	2	18.8	9.51	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002707STMP	000598SMH	000596SMH	18.922	1.5	18.79	10.61	0	0	0.631	-	-	-	0	0	0	0	Surcharged
2	002708STMP	001750IN	000598SMH	35.233	5	18.79	4.07	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002709STMP	001751IN	001750IN	172.647	5	19.42	3.59	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	002710STMP	001752IN	001751IN	31.657	1.25	19.9	18.75	0	0	-	0.405	-	-	0	0	0	0	Sufficient Capacity
2	002712STMP	000599SMH	000170ND	61.153	2	28.45	14.5	0	0	-	1.365	-	-	0	0	0	0	Sufficient Capacity
2	003230STMP	000585SMH	000584SMH	199.652	1.25	17.2	13.69	0.2	0.5	Flooded	Flooded	Flooded	Flooded	0.04333333	0.375	12.61	3446.1	Flooded
2	003237STMP	000586SMH	000585SMH	77.682	1.25	17.38	14.66	0.1	0.2	4.997	Flooded	1.853	Flooded	0	0.04333333	0	12.61	Insufficient Freeboard
2	003240STMP	000587SMH	000586SMH	197.745	1.25	18.26	15.56	0.1	0.1	Flooded	4.897	Flooded	1.853	0.04166667	0	22.76	0	Flooded
2	003253STMP	000588SMH	000589SMH	260.553	7	662.87	17.72	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003254STMP	000589SMH	000119IO	63.478	7.5	-665.49	17.77	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003255STMP	000590SMH	000589SMH	223.411	1.5	3.54	4.66	0	0	-	4.644	-	-	0	0	0	0	Sufficient Capacity
2	003256STMP	001722IN	000120IO	7.216	2.25	18.73	5.91	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003257STMP	001723IN	001722IN	46.991	2	18.71	11.36	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003258STMP	001724IN	001723IN	15.276	2	18.7	9.45	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003265STMP	001729IN	000591SMH	243.232	1.25	20.12	18.24	0	1.1	-	Flooded	-	Flooded	0	0.34333333	0	1393.96	Sufficient Capacity
2	003266STMP	001731IN	001729IN	25.172	1.25	12.53	10.16	0	0	1.089	-	-	-	0	0	0	0	Surcharged
2	003268A	000123IO	000170ND	15.685	7	514.12	22.27	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003268B	000170ND	000219ND	78.203	7	539	28.05	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003268C	000219ND	000125IO	36.599	7	544.87	19.14	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003272A	000600SMH	000217ND	18.709	3	56.23	8.41	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003272B	000217ND	001756IN	8.581	3	56.23	8.69	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003273STMP	000601SMH	000600SMH	126.501	2.5	47.08	9.61	0	0	0.136	-	-	-	0	0	0	0	Surcharged
2	003275STMP	001756IN	001765IN	52.922	4.6	-56.26	9.52	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003276STMP	001759IN	000601SMH	121.65	2.5	41.96	8.55	0	0	0.51	0.136	-	-	0	0	0	0	Surcharged
2	003277STMP	001757IN	000601SMH	30.035	1	6.3	8.89	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003279A	001772IN	000220ND	42.232	1.5	13.29	10.04	0.5	0.7	2.648	Flooded	0.652	Flooded	0	0.15333333	0	8.25	Insufficient Freeboard
2	003279B	000220ND	000232ND	165.451	1.5	24	14.57	0.7	0.9	Flooded	Flooded	Flooded	Flooded	0.15333333	0.445	8.25	4.1	Flooded
2	003279C	000232ND	001759IN	125.1	1.5	28.01	15.61	0.9	0	Flooded	1.51	Flooded	-	0.445	0	4.1	0	Flooded
2	003281STMP	000602SMH	001759IN	197.858	1.25	13.89	14.2	0	0	-	-	1.765	-	0	0	0	0	Sufficient Capacity
2	003282STMP	001761IN	000602SMH	111.461	1.25	13.89	11.11	0.9	0	Flooded	-	Flooded	1.765	0.885	0	7559.11	0	Flooded
2	003283STMP	001762IN	001761IN	31.501	1.25	10.67	5.89	0.9	0.9	Flooded	Flooded	Flooded	Flooded	0.54666667	0.885	1606.42	7559.11	Flooded
2	003288STMP	001765IN	000604SMH	17.882	4.6	56.31	15.83	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003289STMP	000604SMH	001768IN	157.691	3	56.31	7.92	0	0.4	2.931	1.835	-	0.865	0	0	0	0	Surcharged
2	003290STMP	001767IN	000219ND	17.607	1.5	7.56	24.08	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity

TABLE 1

Strawberry Run Hydraulic Model Detailed Results

		Junction FaciltiyID						Duration of Surcharge (hrs)		Surcharge/ Depth Above Crown (ft)		Insufficient Freeboard/ Depth Below Rim (ft)		Duration of Flooding (hrs)		Flooded Volume (ft3)		
Subshed	DGravityMain FacilityID	US	DS	Length (ft)	Diameter/ Height x Width (ft)	Maximum Flow (ft3/s)	Maximum Velocity (fps)	US	DS	US	DS	US	DS	US	DS	US	DS	Summary Pipe Condition
2	003291STMP	000595SMH	001767IN	229.197	1.5	7.56	12.12	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
2	003292STMP	001410IN	001770IN	224.311	1.25	15.24	12.96	0.6	1	Flooded	Flooded	Flooded	Flooded	0.58	0.95333333	640.19	4387.35	Flooded
2	003293STMP	001769IN	000220ND	75.263	1.25	17.49	14.11	1	0.7	4.443	Flooded	0.007	Flooded	0	0.15333333	0.04	8.25	Insufficient Freeboard
2	003294STMP	001770IN	001769IN	28.296	1.25	17.49	13.99	1	1	Flooded	4.443	Flooded	0.007	0.95333333	0	4387.35	0.04	Flooded
2	003295STMP	001771IN	001772IN	37.846	1.25	13.31	11.36	0.3	0.5	2.367	2.398	0.483	0.652	0	0	0	0	Insufficient Freeboard
2	014713STMP	000414SMH	000211ND	30.388	6	366.04	18.36	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	000881STMP	000432SMH	001402IN	92.495	3	56.78	9.97	0	0	-	0.101	-	-	0	0	0	0	Sufficient Capacity
3	000882STMP	001402IN	001403IN	148.465	3	56.9	7.86	0	0	0.301	-	-	-	0	0	0	0	Surcharged
3	000883STMP	001403IN	000433SMH	172.033	3	56.92	29.54	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	002006STMP	001312IN	000412SMH	53.228	1.5	18.83	10.91	0	0	0.132	-	-	-	0	0	0	0	Surcharged
3	002196STMP	000412SMH	000413SMH	103.541	4	276.39	24.93	0	0.2	0.214	0.662	-	-	0	0	0	0	Surcharged
3	002197STMP	001314IN	000412SMH	74.19	4	257.66	24.18	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	002200STMP	000091IO	000413SMH	91.331	3.5	144.17	14.84	0.3	0.2	7.675	6.162	1.148	-	0	0	0	0	Insufficient Freeboard
3	002201STMP	000413SMH	000414SMH	84.811	4.5	366.01	22.84	0.2	0	5.962	-	-	-	0	0	0	0	Surcharged
3	002388STMP	001272IN	001273IN	38.19	1.25	19.93	18.76	0	0.2	0.283	1.025	-	-	0	0	0	0	Surcharged
3	002389STMP	001286IN	001272IN	233.683	1.25	10.96	8.82	0.3	0	2.465	0.183	-	-	0	0	0	0	Surcharged
3	002390STMP	001273IN	001274IN	30.501	1.25	19.93	16.17	0.2	0	1.025	-	-	-	0	0	0	0	Surcharged
3	002391STMP	001274IN	001275IN	46.142	1.25	19.94	19.56	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	002392STMP	001275IN	001278IN	376.358	1.5	25.98	20.16	0	0	-	4.366	-	0.734	0	0	0	0	Sufficient Capacity
3	002394STMP	001278IN	001282IN	34.719	1.25	34.65	27.64	0	0	4.716	-	0.734	-	0	0	0	0	Insufficient Freeboard
3	002396STMP	001281IN	001278IN	41.41	1.25	8.81	13.49	0.1	0	1.645	4.116	-	0.734	0	0	0	0	Surcharged
3	002401STMP	000433SMH	000498SMH	140.147	3	69.74	16.88	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	002403STMP	001282IN	000499SMH	113.16	3.5	127.15	20.78	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	002404STMP	001285IN	001282IN	77.718	3.5	92.81	18.12	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	002405STMP	000498SMH	001285IN	86.483	3.5	69.79	16.22	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	002406STMP	001288IN	001286IN	25.776	1.25	11.16	8.98	0	0.3	2.587	2.365	-	-	0	0	0	0	Surcharged
3	002408STMP	001289IN	001288IN	45.282	1.25	11.5	9.24	0.3	0	2.959	2.487	-	-	0	0	0	0	Surcharged
3	002417STMP	000499SMH	000104IO	61.84	3.5	127.21	18.34	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	003750STMP	002891IN	000432SMH	230.526	3	50.05	10.95	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	003751STMP	002896IN	002891IN	126.086	2.5	49.8	10.17	0	0	0.822	-	-	-	0	0	0	0	Surcharged
3	004013STMP	000896SMH	002895IN	128.549	1.5	25.49	17.19	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
3	004015STMP	002895IN	000182IO	95.118	1.75	25.5	17.04	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000437STMP	001358IN	000423SMH	188.702	1.5	11.21	14.76	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000438STMP	000423SMH	001359IN	69.229	1.5	11.22	13.33	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000440STMP	001359IN	001360IN	73.877	1.5	11.22	12.75	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000441STMP	001360IN	001353IN	192.2	1.5	11.22	10.96	0	0.3	-	Flooded	-	Flooded	0	0.25333333	0	1399.4	Sufficient Capacity
4	000830STMP	001352IN	000430SMH	154.008	1.5	26.99	15.06	0	0	3.682	-	-	-	0	0	0	0	Surcharged
4	000831STMP	001353IN	001352IN	166.204	1.5	26.99	14.88	0.3	0	Flooded	2.532	Flooded	-	0.25333333	0	1399.4	0	Flooded
4	000833STMP	001355IN	000422SMH	177.109	1.5	11.21	8.81	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000835STMP	000422SMH	001358IN	96.281	1.5	11.22	14.27	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000871STMP	001393IN	001392IN	47.884	4	196.06	24.67	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000872STMP	001394IN	001393IN	50.468	4	196.03	16.81	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000873STMP	000431SMH	001394IN	123.607	4	181.41	15.28	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000874STMP	001395IN	001394IN	55.64	1.5	15.85	14.46	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000875STMP	001396IN	001395IN	209.056	1.25	15.84	13.7	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	000877STMP	001398IN	000431SMH	155.265	4	181.71	14.03	0	0	0.566	-	-	-	0	0	0	0	Surcharged
4	000878STMP	001401IN	001398IN	245.272	4	170.03	14.38	0	0	0.365	0.266	-	-	0	0	0	0	Surcharged
4	002198STMP	000421SMH	001314IN	281.042	4	256.57	31.19	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity

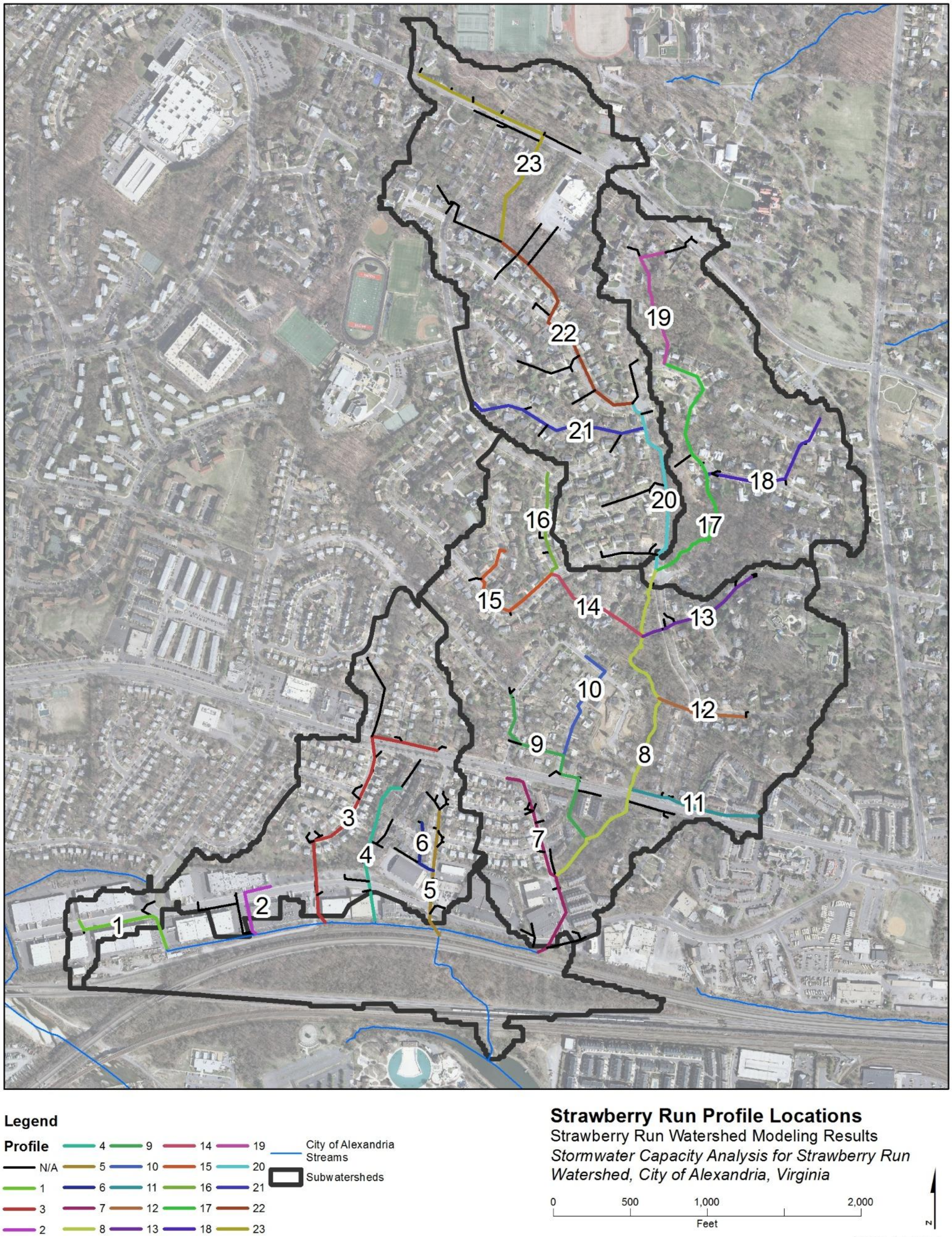
TABLE 1

Strawberry Run Hydraulic Model Detailed Results

Subshed	DGravityMain FacilityID	Junction FaciltiyID		Length (ft)	Diameter/ Height x Width (ft)	Maximum Flow (ft3/s)	Maximum Velocity (fps)	Duration of Surcharge (hrs)		Surcharge/ Depth Above Crown (ft)		Insufficient Freeboard/ Depth Below Rim (ft)		Duration of Flooding (hrs)		Flooded Volume (ft3)		Summary Pipe Condition
		US	DS					US	DS	US	DS	US	DS	US	DS	US	DS	
4	002438STMP	000411SMH	001312IN	178.494	1.25	18.87	14.93	0.2	0	Flooded	0.282	Flooded	-	0.10333333	0	120.59	0	Flooded
4	002448STMP	001337IN	001339IN	102.554	1.25	16.93	13.44	0.1	0.4	5.517	2.615	1.183	1.185	0	0	0	0	Insufficient Freeboard
4	002450STMP	001339IN	001341IN	53.992	1.25	16.92	13.75	0.4	0	2.665	-	1.185	-	0	0	0	0	Insufficient Freeboard
4	002452STMP	001341IN	001342IN	73.866	1.75	16.94	11.1	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002453STMP	001342IN	000421SMH	122.072	4	248.57	24.13	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002454STMP	001390IN	001342IN	234.702	4	230.63	22.73	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002474STMP	001392IN	000430SMH	90.083	4	196.06	20.26	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002475STMP	000430SMH	001389IN	96.19	4	223.07	22.81	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002476STMP	001389IN	001390IN	96.156	4	223.74	24.53	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002887STMP	002862IN	002861IN	267.292	1.25	9.4	7.64	0.5	0.2	Flooded	Flooded	Flooded	Flooded	0.44833333	0.095	2019.75	115.93	Flooded
4	002888STMP	002863IN	000889SMH	14.874	1.75	16.5	8.61	0.2	0.2	0.983	1.531	0.967	0.219	0	0	0	0	Insufficient Freeboard
4	002889STMP	002864IN	000889SMH	15.539	1.75	22.53	9.53	0.2	0.2	1.033	1.531	0.917	0.219	0	0	0	0	Insufficient Freeboard
4	002890STMP	002861IN	002864IN	51.307	1.25	15.9	6.72	0.2	0.2	Flooded	1.533	Flooded	0.917	0.095	0	115.93	0	Flooded
4	002891STMP	000889SMH	002865IN	281.651	1.75	38.69	17.13	0.2	0.3	4.831	4.122	0.219	0.828	0	0	0	0	Insufficient Freeboard
4	002892STMP	002865IN	002867IN	130.897	2	52.38	16.4	0.3	0.3	5.372	3.555	0.828	1.445	0	0	0	0	Insufficient Freeboard
4	002894STMP	002866IN	000891SMH	139.196	3	88.15	14.26	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002895STMP	002867IN	002866IN	291.681	2	52.4	16.45	0.3	0	4.955	0.734	1.445	-	0	0	0	0	Insufficient Freeboard
4	002896STMP	002868IN	000891SMH	175.835	1.25	10.23	16.99	0	0	-	0.315	-	-	0	0	0	0	Sufficient Capacity
4	002898STMP	002870IN	002871IN	235.857	3.5	120.67	13.1	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002899STMP	000891SMH	002870IN	92.223	3	105.61	14.61	0	0	0.665	-	-	-	0	0	0	0	Surcharged
4	002900STMP	002889IN	002870IN	305.195	1.75	15.27	13.68	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002901STMP	002871IN	000892SMH	76.941	3.5	131.89	17.99	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002902STMP	000892SMH	002875IN	105.498	3.5	131.54	16.42	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002904STMP	002873IN	002875IN	125.11	1.5	7.21	14.82	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002905STMP	002874IN	002876IN	91.143	3.5	138	14.83	0	0	0.393	0.294	-	-	0	0	0	0	Surcharged
4	002906STMP	002875IN	002874IN	42.947	3.5	138.23	15.96	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	002907STMP	002876IN	002877IN	71.524	4	151.96	12.66	0	0	0.094	-	-	-	0	0	0	0	Surcharged
4	002908STMP	002877IN	001401IN	152.752	4	151.89	12.06	0	0	1.174	0.065	-	-	0	0	0	0	Surcharged
4	003602STMP	002878IN	001401IN	41.279	1.75	19.19	9.82	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	003603STMP	002879IN	002878IN	52.609	1.5	19.18	10.81	0	0	1.125	-	-	-	0	0	0	0	Surcharged
4	003748STMP	002888IN	002846IN	136.638	1.5	13.28	10.09	0	0.1	-	0.47	-	-	0	0	0	0	Sufficient Capacity
4	004558STMP	002846IN	002847IN	33.004	1.25	13.29	10.79	0.1	0	0.72	-	-	-	0	0	0	0	Surcharged
4	004561STMP	002847IN	002848IN	35.238	3	22.82	10.19	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	004562STMP	000886SMH	002847IN	86.622	1.25	9.51	10.2	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	004563STMP	002848IN	000885SMH	6.844	3	22.83	7.44	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	004564STMP	000885SMH	000887SMH	101.534	3	22.9	7.53	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	004566STMP	000887SMH	002866IN	331.882	2.5	36.54	17.23	0	0	-	0.234	-	-	0	0	0	0	Sufficient Capacity
4	004570STMP	002852IN	002864IN	230.02	1.25	7.17	5.8	0.2	0.2	Flooded	1.533	Flooded	0.917	0.05666667	0	19.38	0	Flooded
4	004572STMP	002856IN	002857IN	99.595	1.25	7.5	6.14	0.1	0	0.437	-	1.913	-	0	0	0	0	Insufficient Freeboard
4	004574STMP	002857IN	002858IN	160.187	1.5	7.45	5.48	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity
4	004575STMP	002858IN	002859IN	199.183	1.5	7.33	5.91	0	0.1	-	0.865	-	0.535	0	0	0	0	Sufficient Capacity
4	004577STMP	002859IN	002861IN	306.442	1.5	15.04	5.27	0.1	0.2	0.965	Flooded	0.535	Flooded	0	0.095	0	115.93	Insufficient Freeboard
4	004579STMP	002854IN	002852IN	90.93	1.25	7.84	6.83	0.2	0.2	1.83	Flooded	0.12	Flooded	0	0.05666667	0	19.38	Insufficient Freeboard
4	004580STMP	000181IO	002861IN	13.31	1.5	10.11	6.29	0.1	0.2	0.61	Flooded	0.89	Flooded	0	0.095	0	115.93	Insufficient Freeboard
4	004581STMP	002861IN	002863IN	51.331	1.25	17.05	6.99	0.2	0.2	Flooded	1.483	Flooded	0.967	0.095	0	115.93	0	Flooded
4	004582STMP	000893SMH	002879IN	131.051	1.5	19.18	10.71	0.3	0	3.453	0.375	-	-	0	0	0	0	Surcharged
4	004584STMP	002881IN	000893SMH	39.535	1.5	19.21	11.79	0	0.3	2.607	3.353	-	-	0	0	0	0	Surcharged
4	004585STMP	000895SMH	002881IN	64.767	1.25	19.34	20.39	0	0	-	-	-	-	0	0	0	0	Sufficient Capacity

TABLE 2
Strawberry Run Outfall Boundary Conditions

Node ID	Location	Boundary Condition
000119IO	Strawberry Run	Type2, Fixed Backwater
000120IO	Strawberry Run	Type 1, Free Outfall
000130IO	Strawberry Run	Type 1, Free Outfall
000133IO	Strawberry Run	Type 1, Free Outfall
000134IO	Strawberry Run	Type 1, Free Outfall
000135IO	Strawberry Run	Type 1, Free Outfall
000610IO	Strawberry Run	Type 1, Free Outfall



Strawberry Run Profile Locations

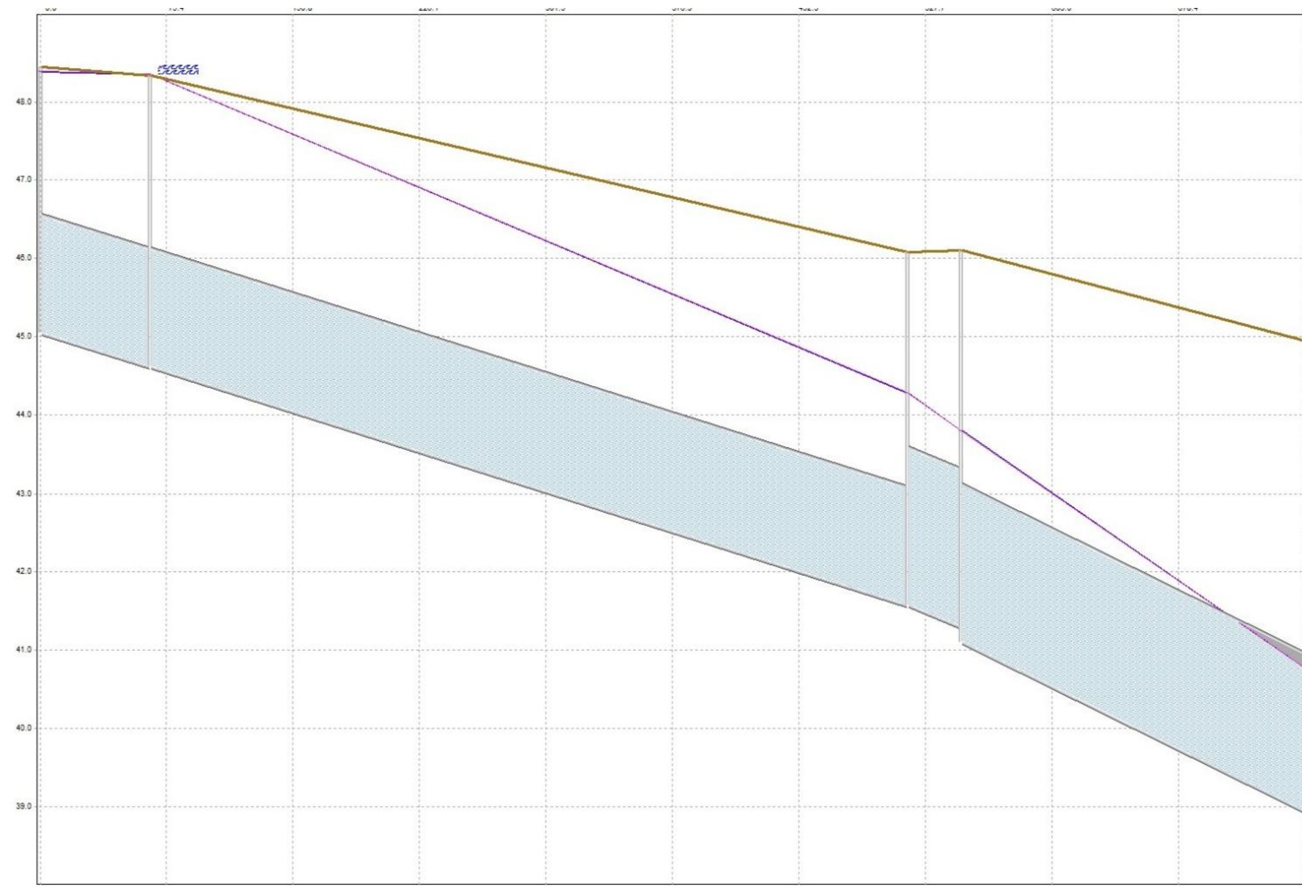
Strawberry Run Watershed Modeling Results

Stormwater Capacity Analysis for Strawberry Run Watershed, City of Alexandria, Virginia

CH2MHILL

FIGURE 1

Strawberry Run Profile 1 from 002050IN to 000610IO



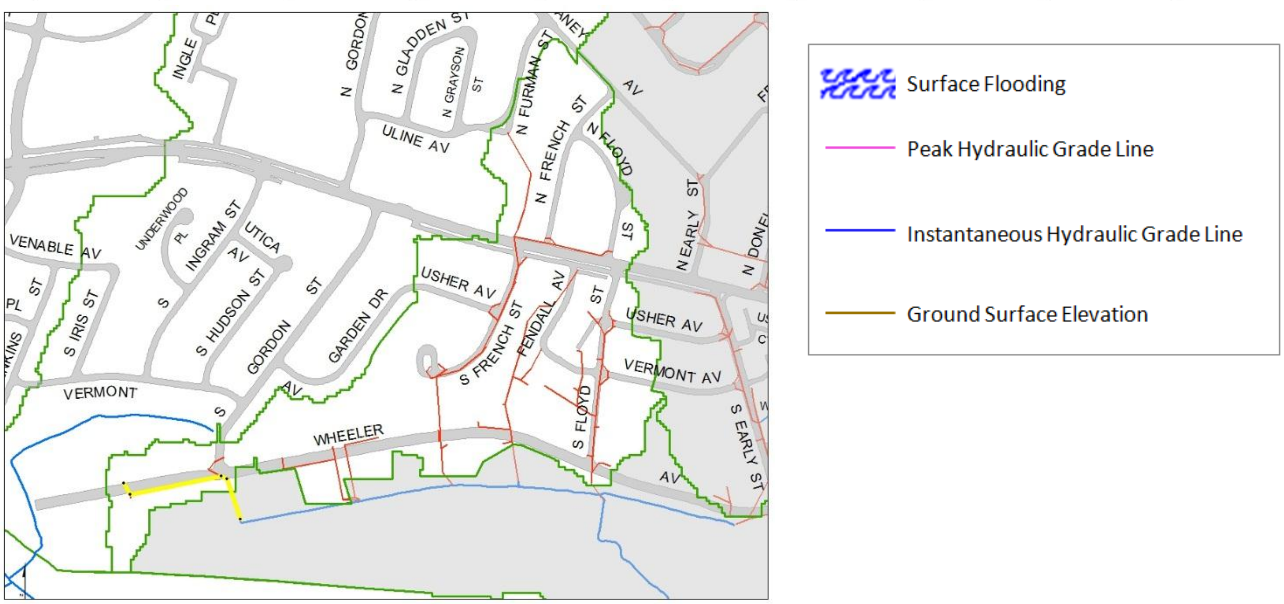
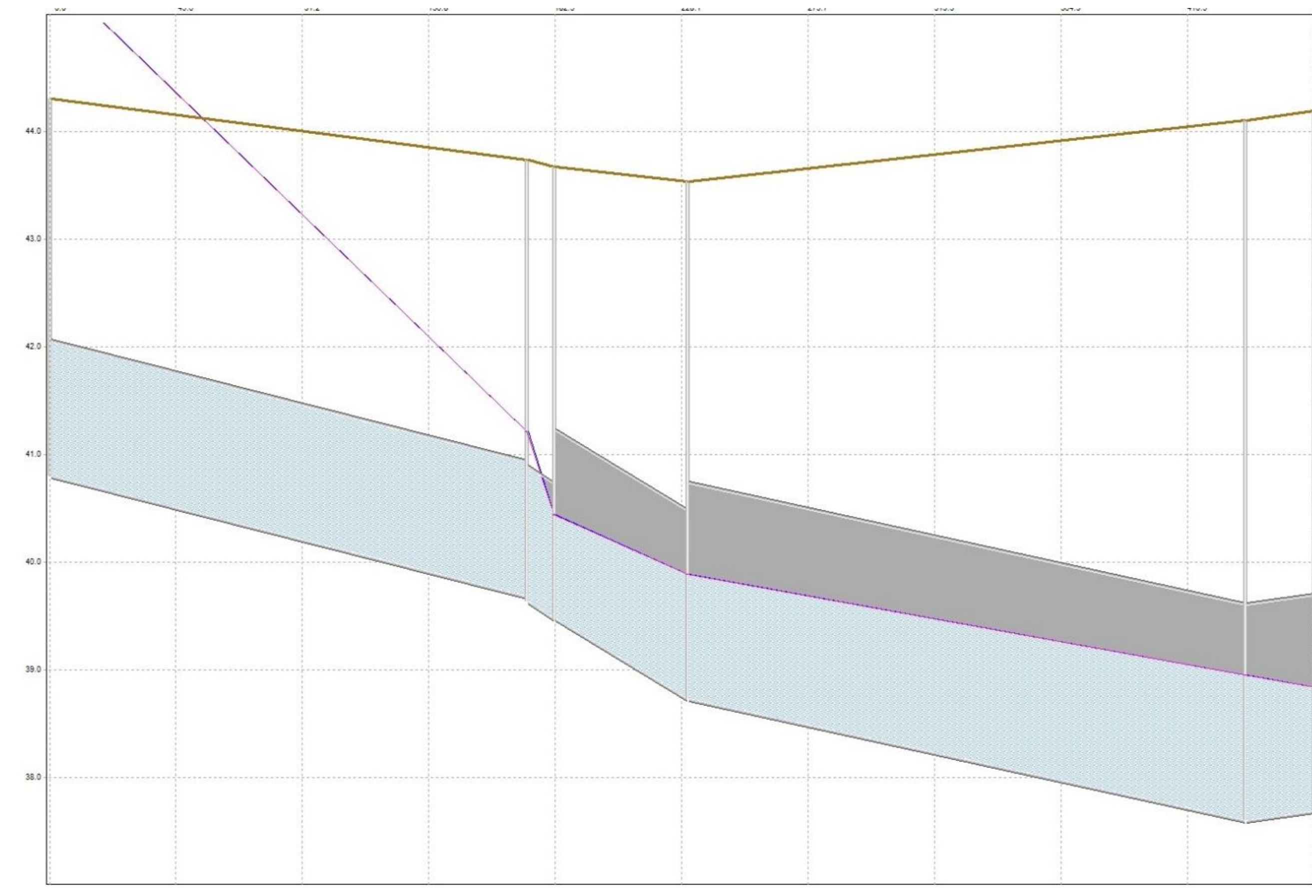


FIGURE 2

Strawberry Run Profile 2 from 001851IN to 000133IO



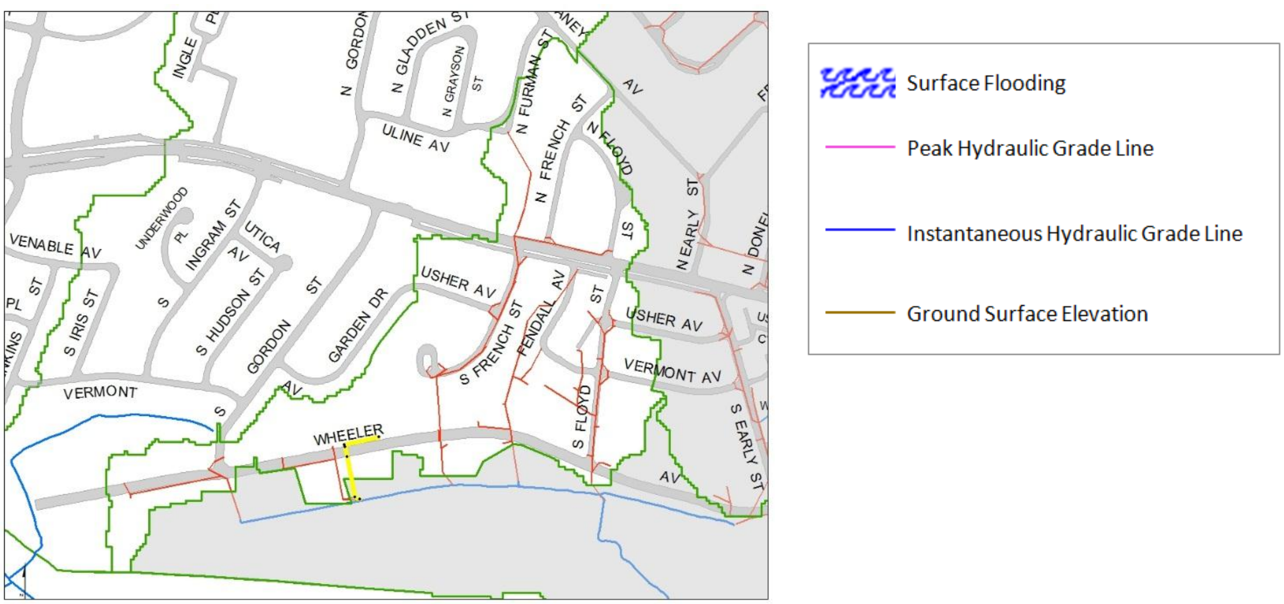


FIGURE 3

Strawberry Run Profile 3 from 001807IN to 000134IO

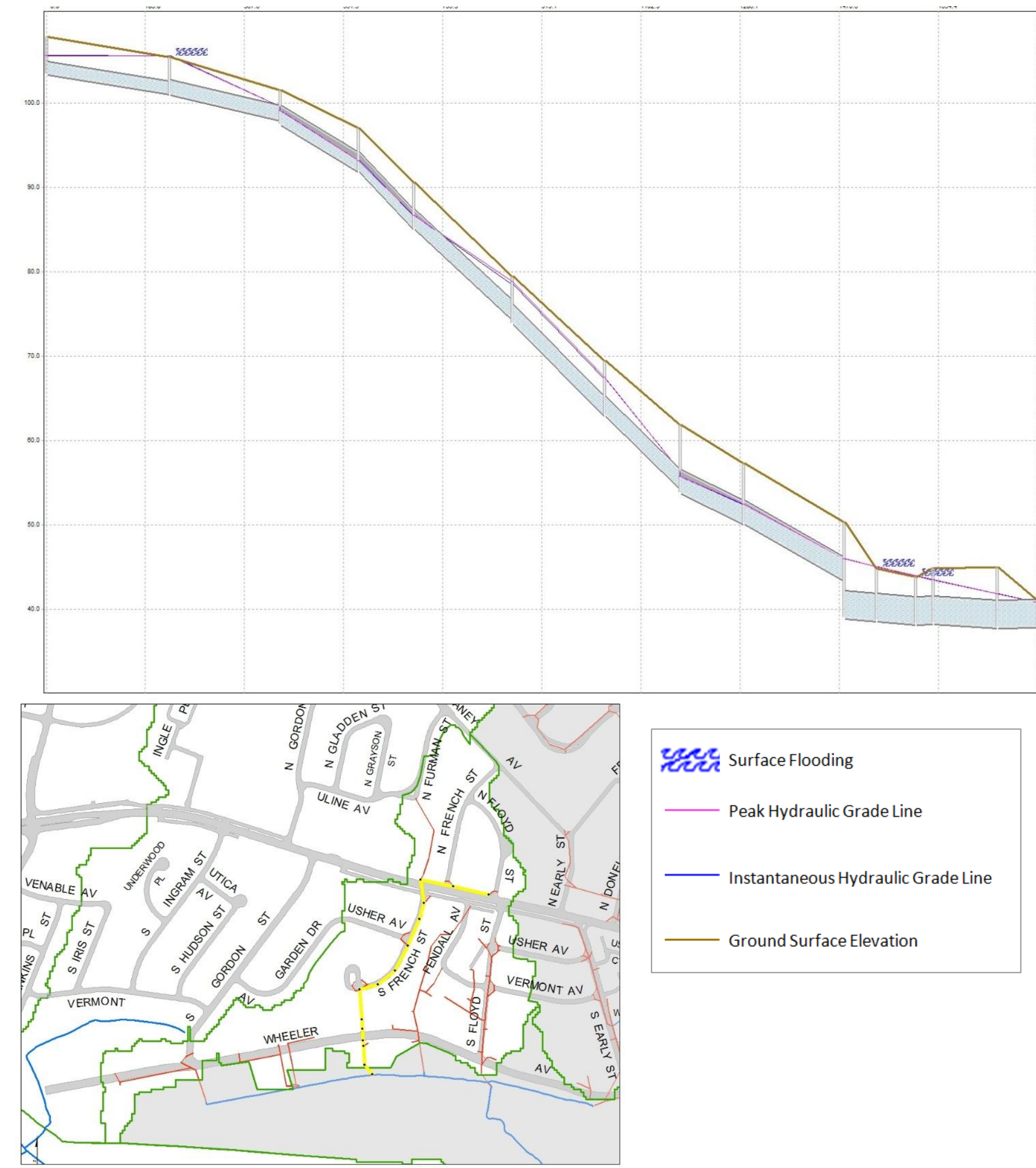


FIGURE 4

Strawberry Run Profile 4 from 000608SMH to 000130IO

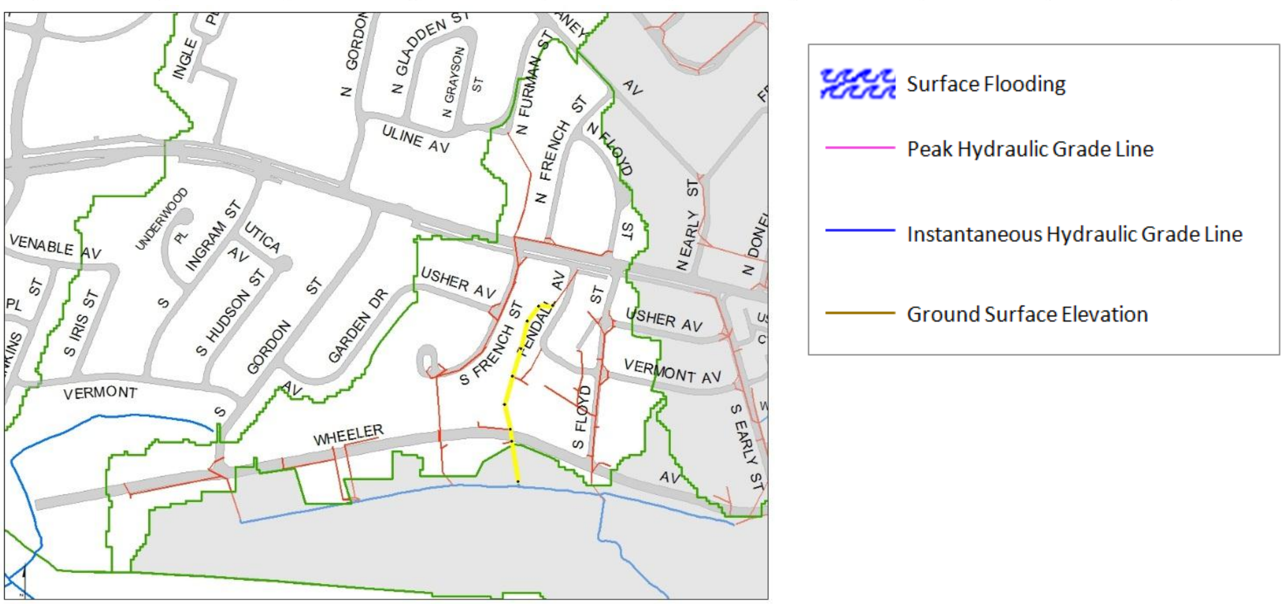
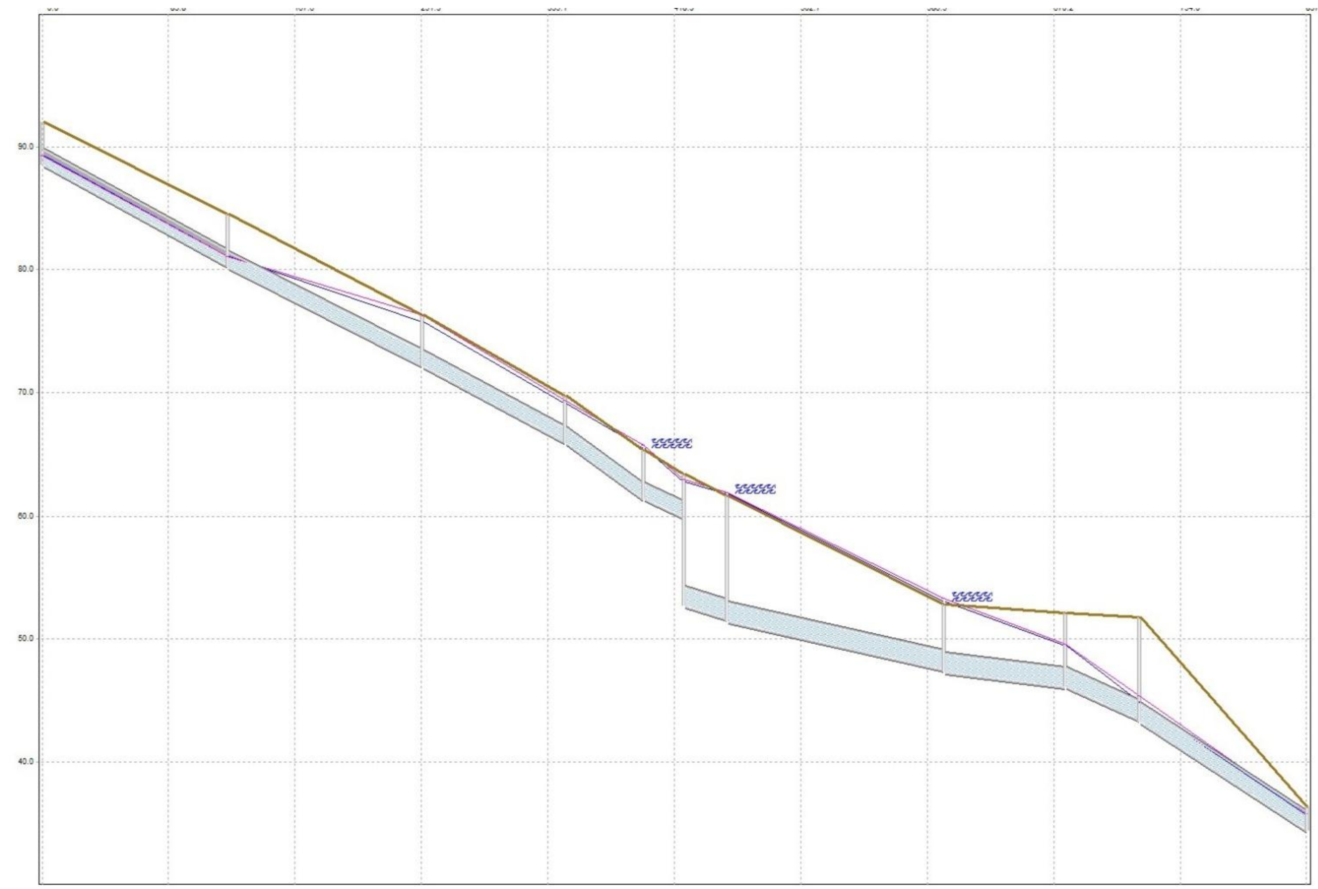


FIGURE 5

Strawberry Run Profile 5 from 000605SMH to 000135IO



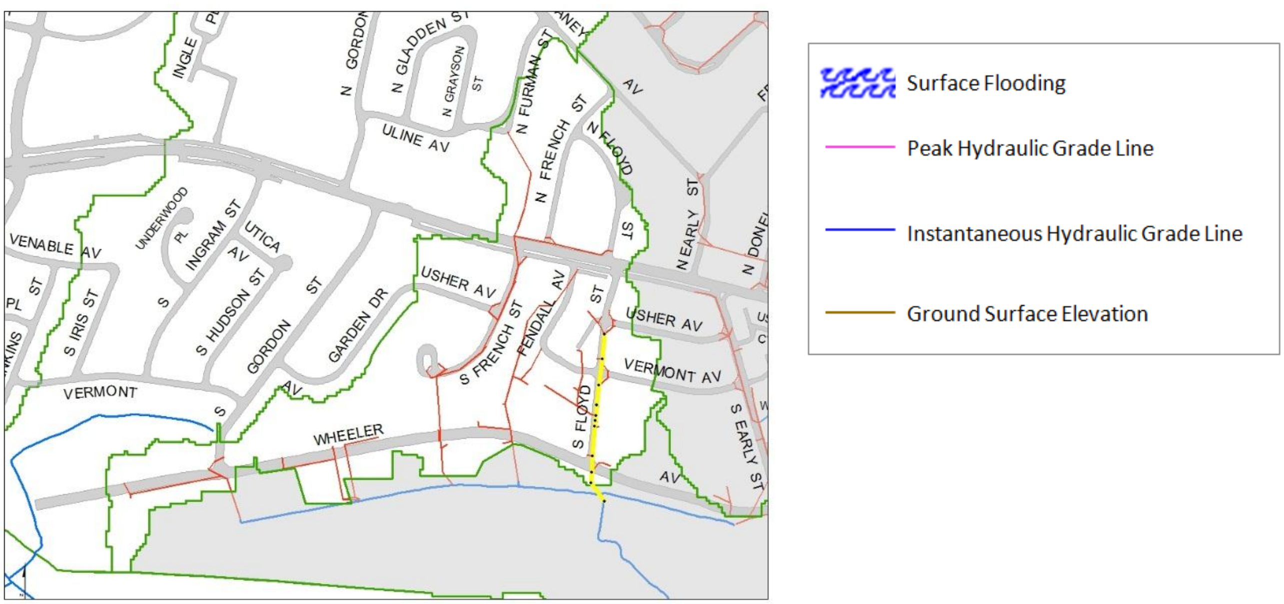
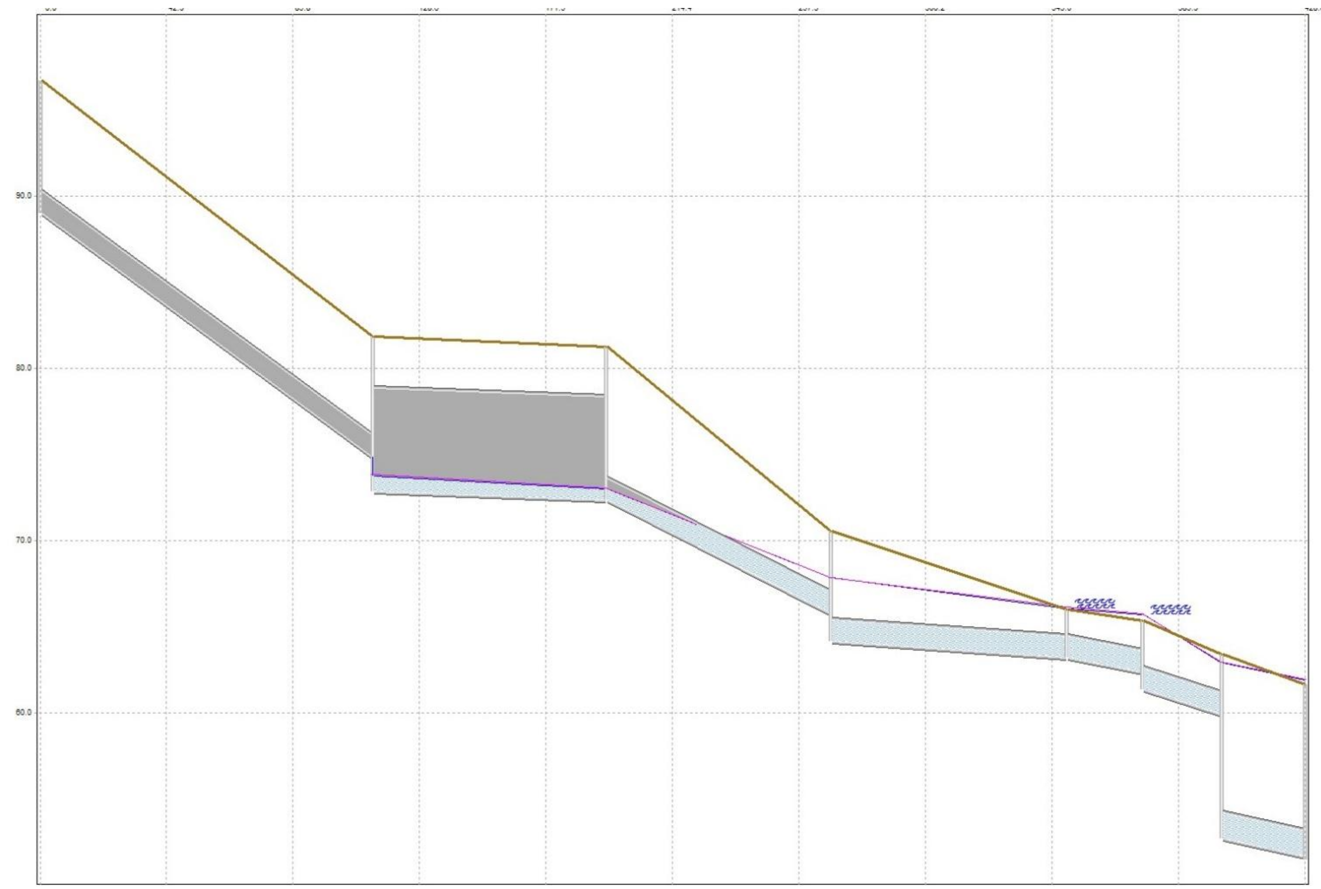


FIGURE 6

Strawberry Run Profile 6 from 001785IN to 000614SMH



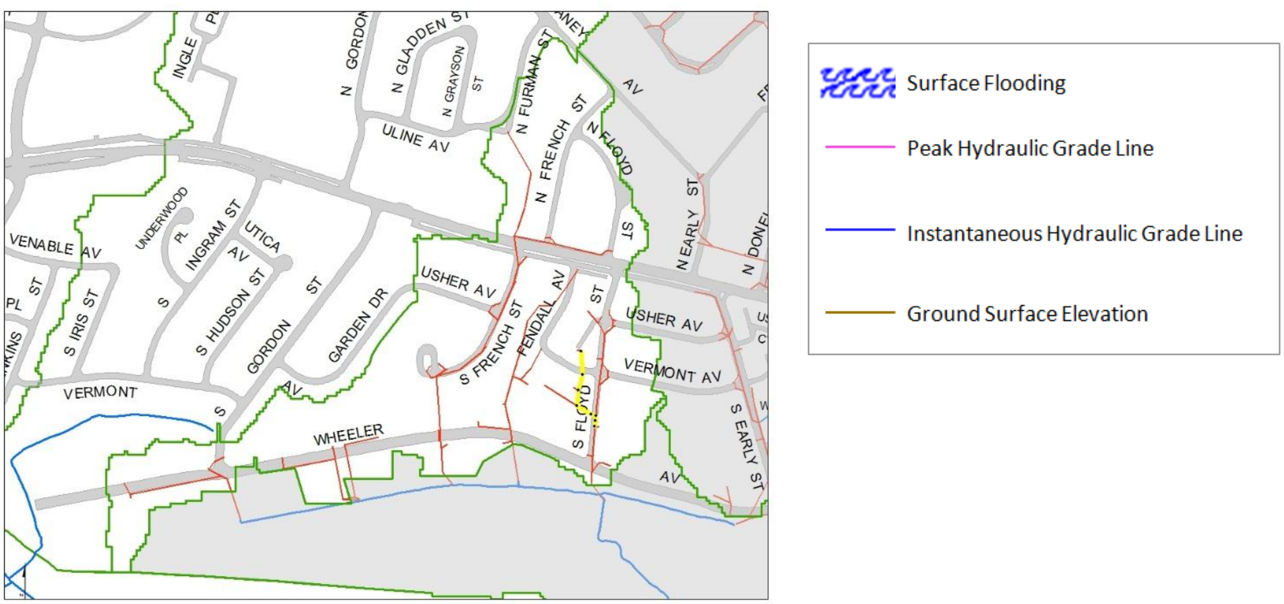
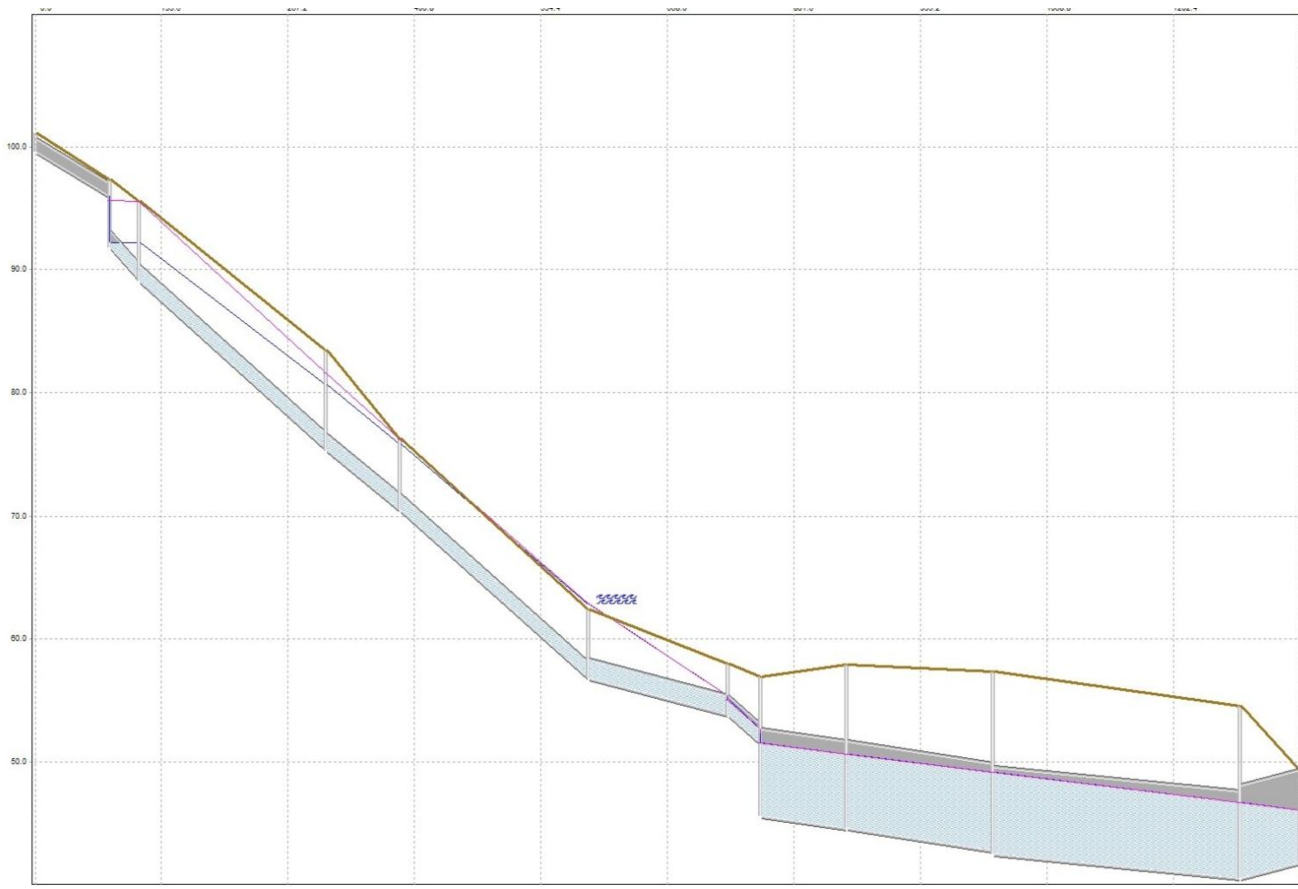


FIGURE 7

Strawberry Run Profile 7 from 000218ND to 000119IO



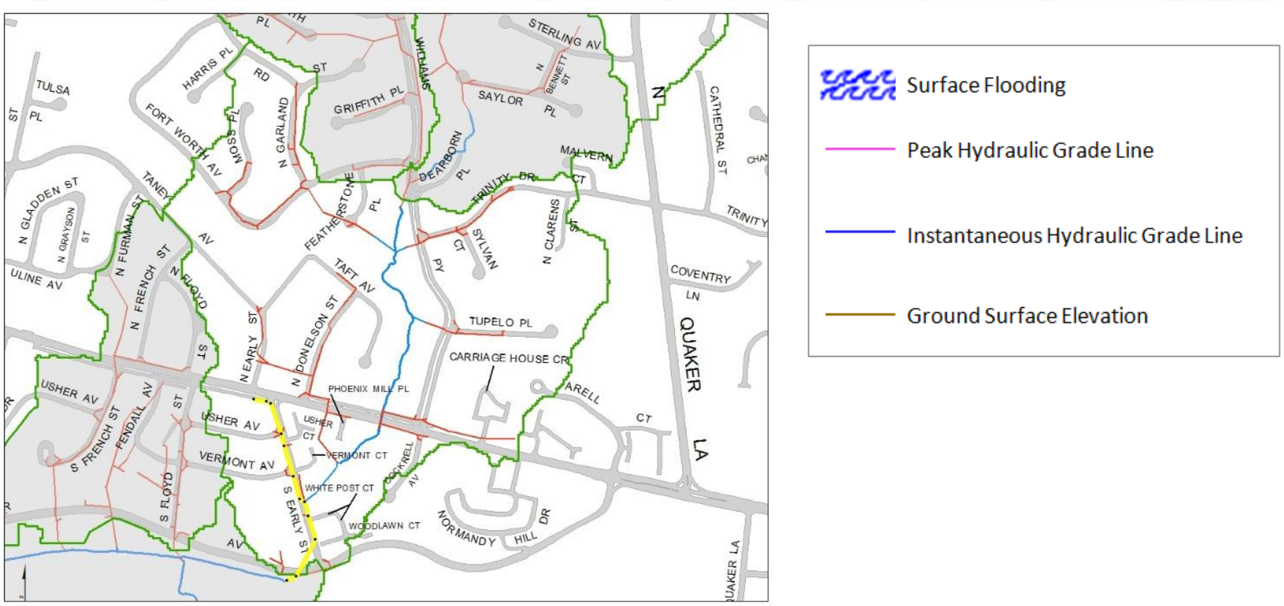
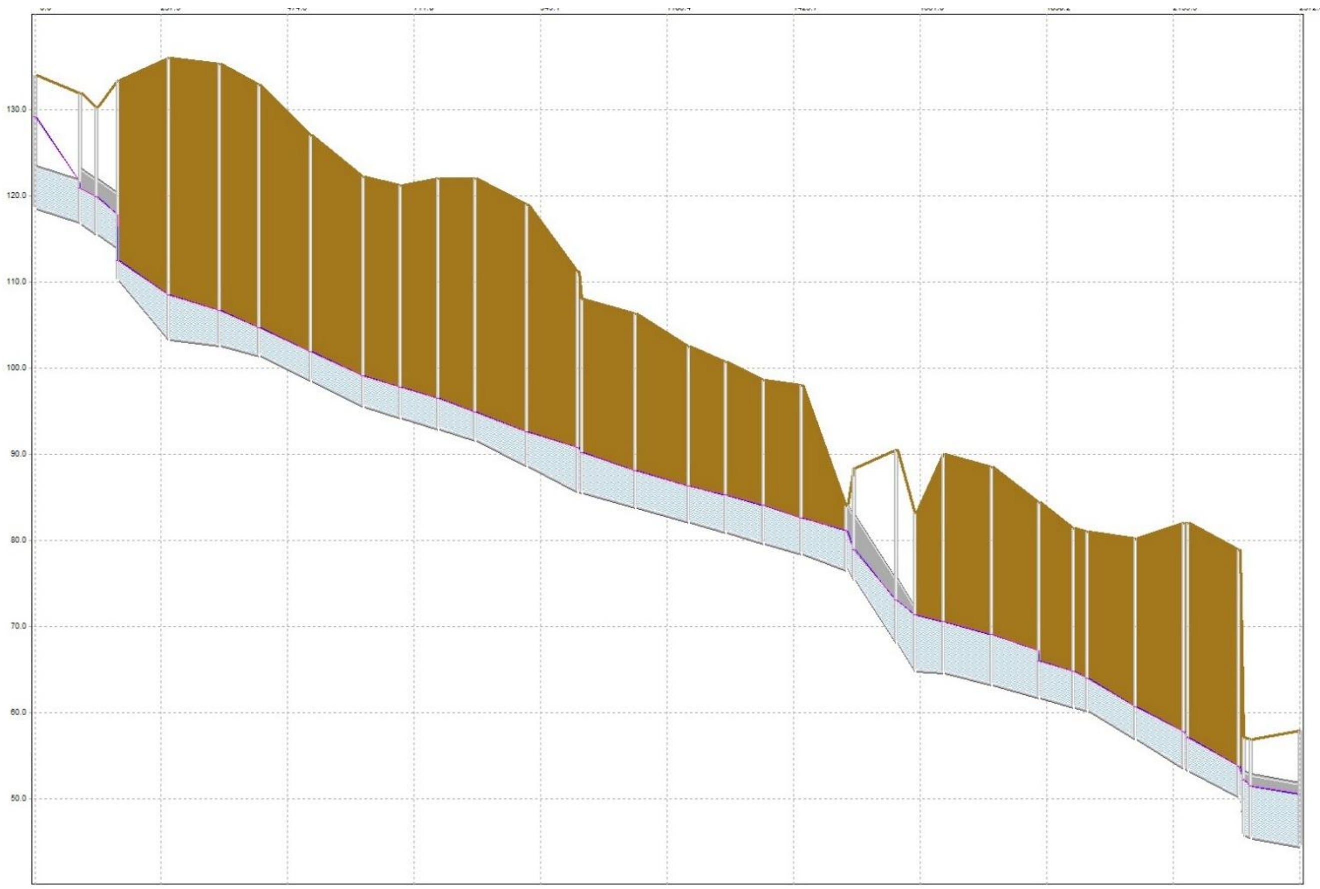


FIGURE 8

Strawberry Run Profile 8 from 000413SMH to 000169ND



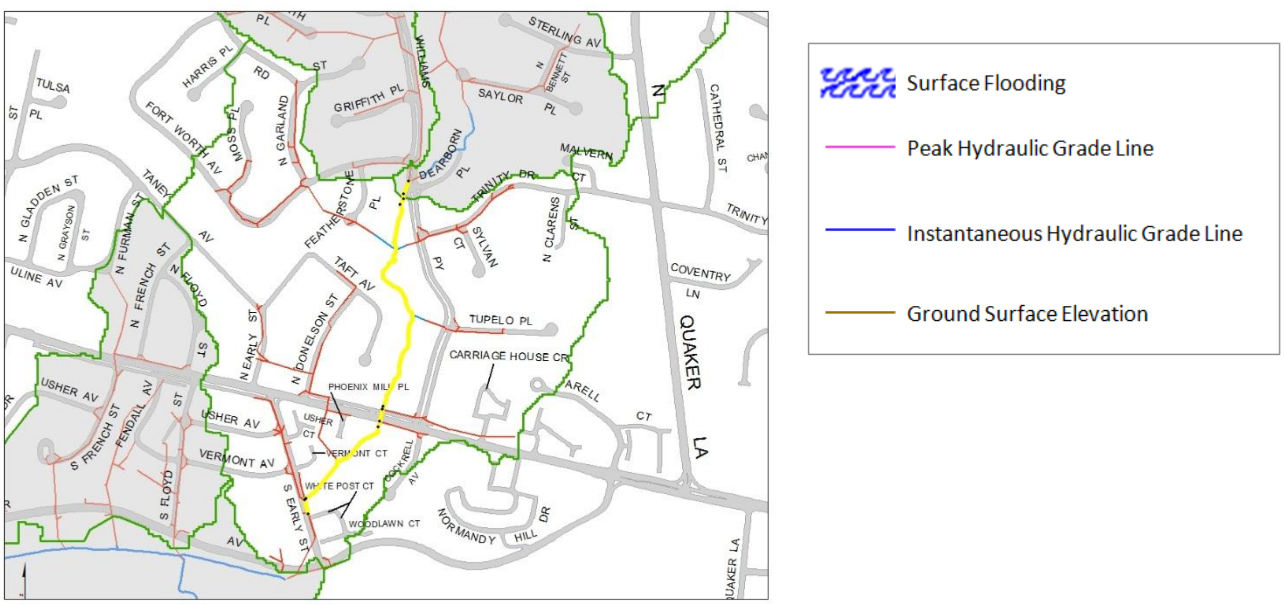


FIGURE 9

Strawberry Run Profile 9 from 000221ND to 000169ND

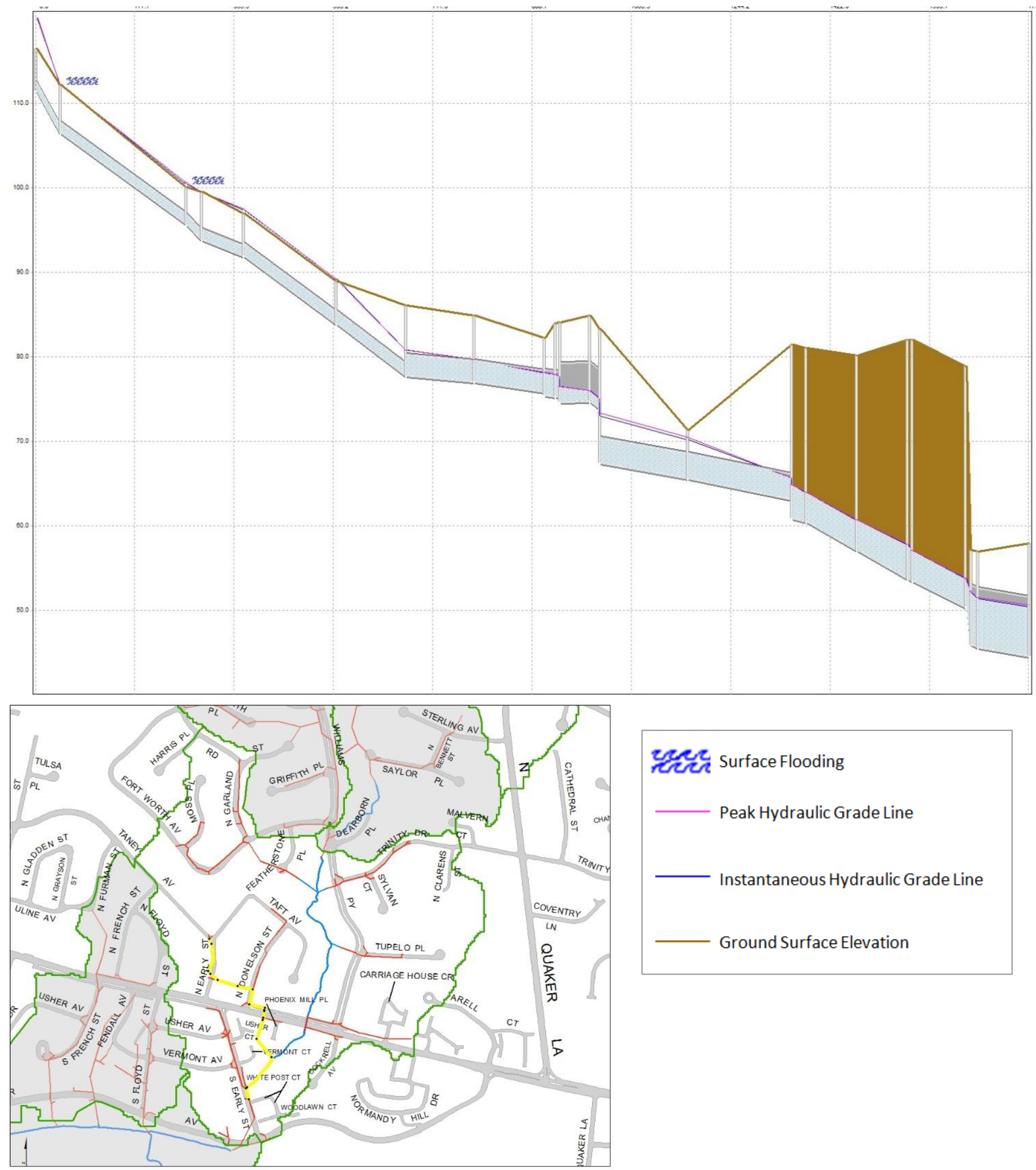
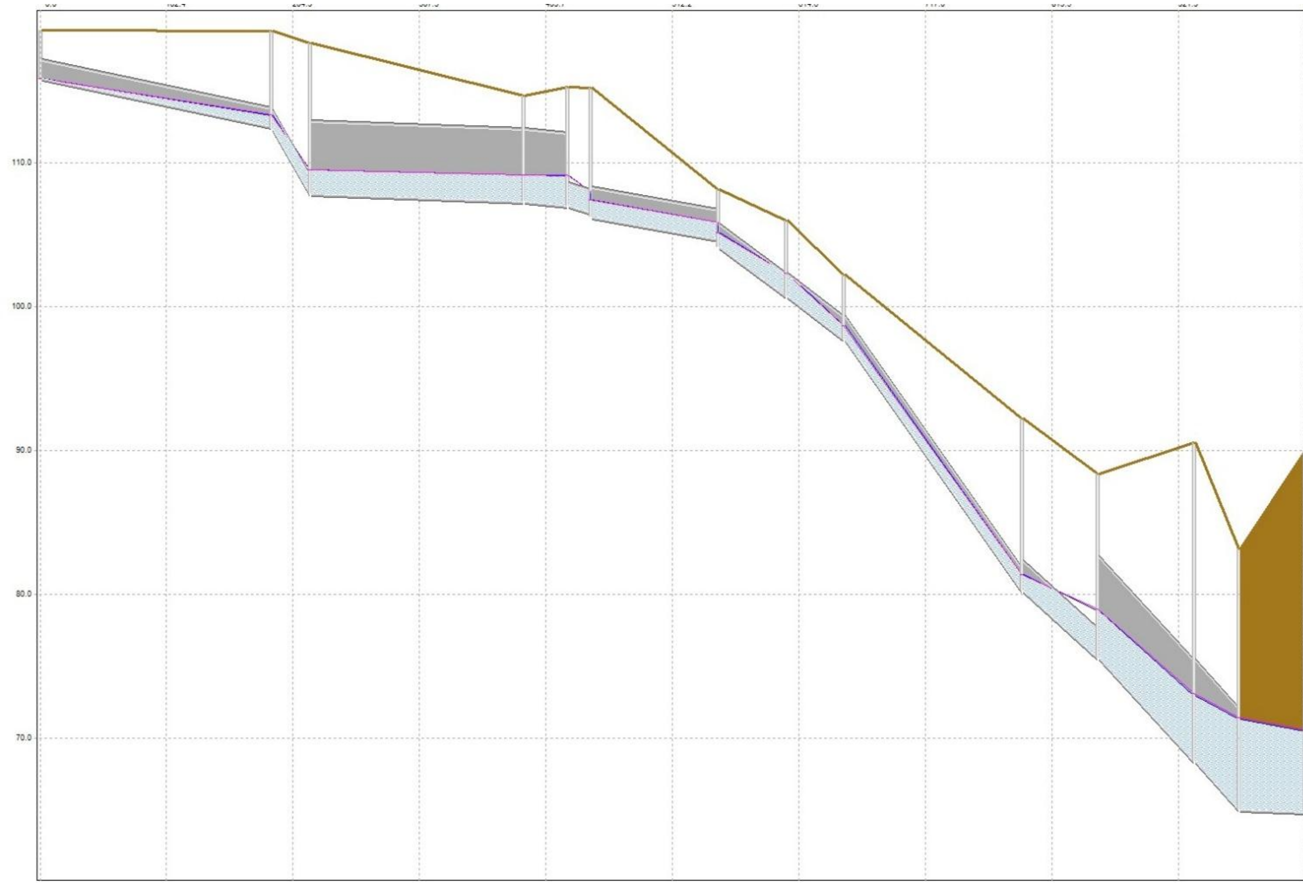


FIGURE 10

Strawberry Run Profile 10 from 001407IN to 000600SMH

FIGURE 11

Strawberry Run Profile 11 from 001753IN to ND_0.710



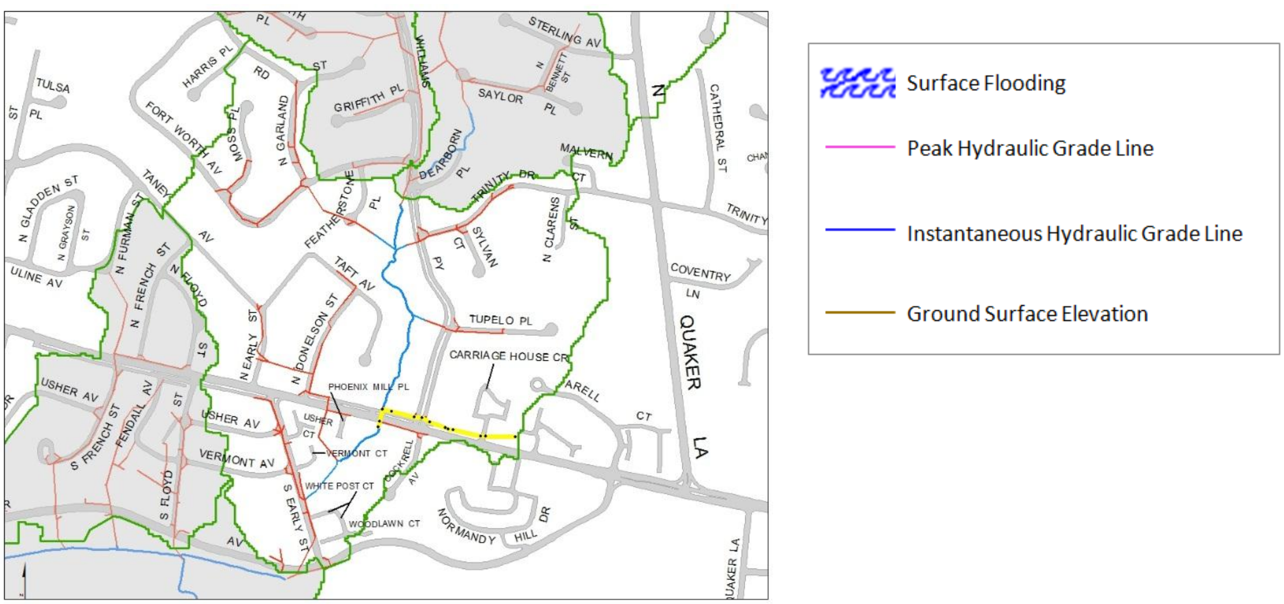


FIGURE 12

Strawberry Run Profile 12 from 001728IN to ND_0.850

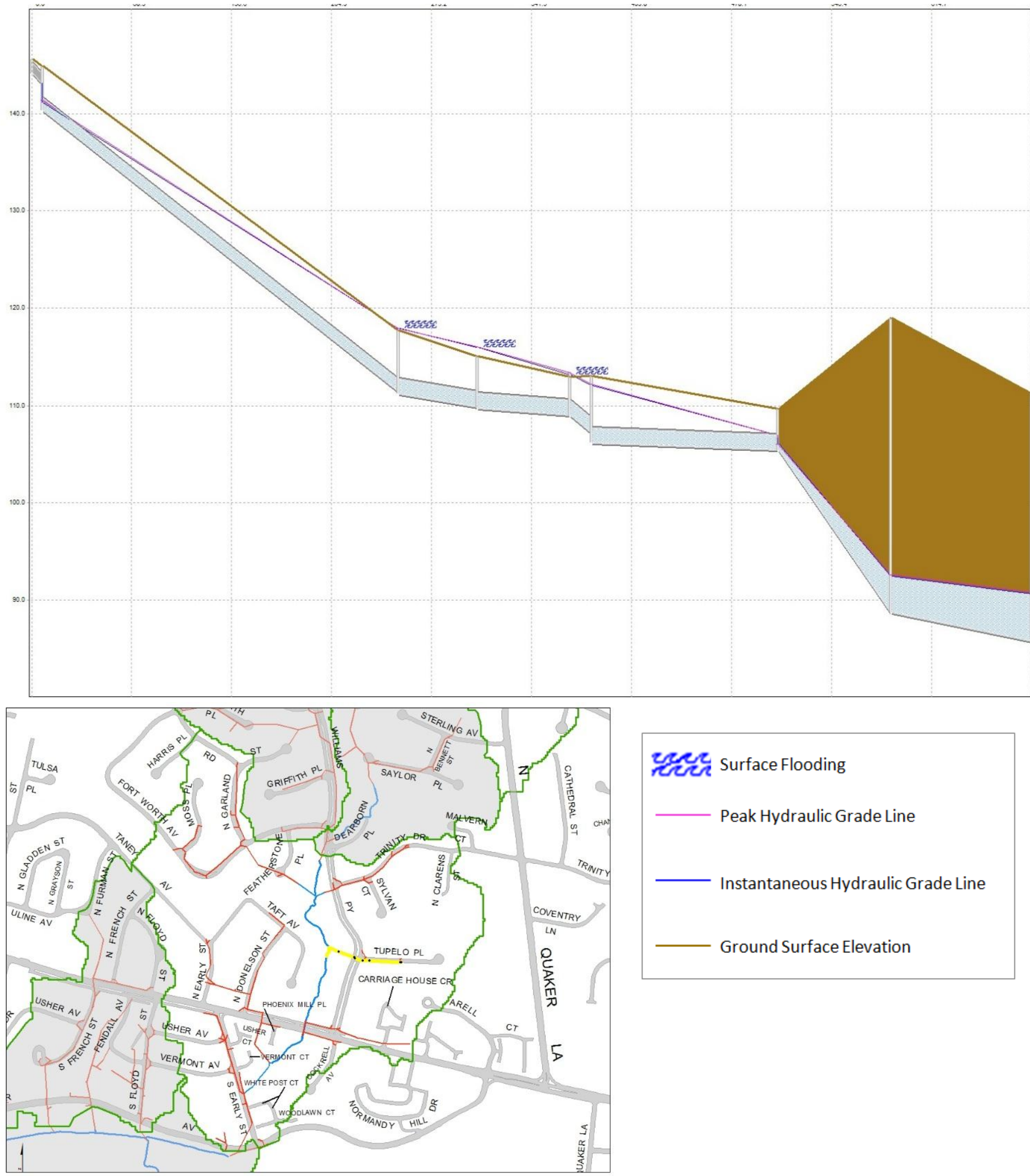
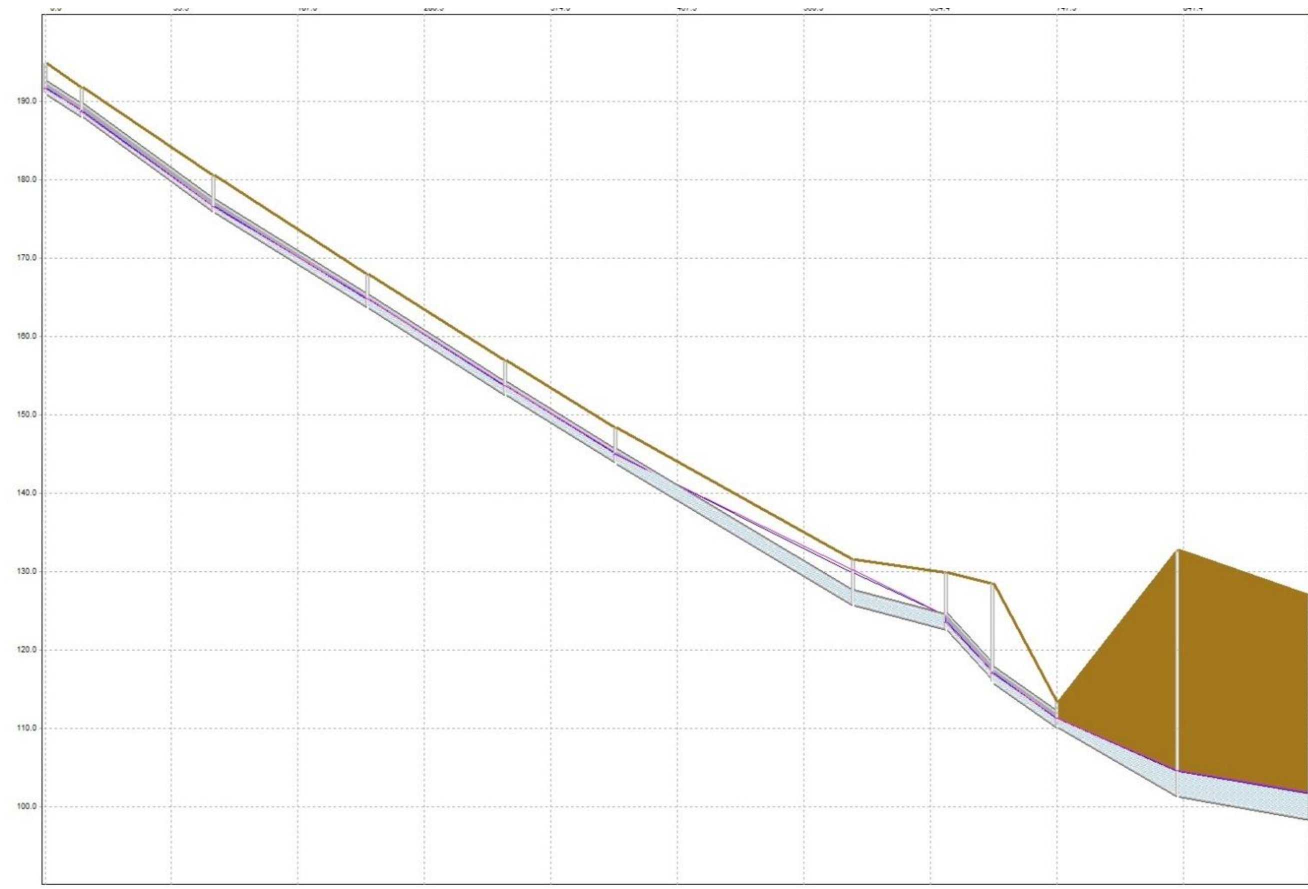


FIGURE 13

Strawberry Run Profile 13 from 001261IN to ND_0.945



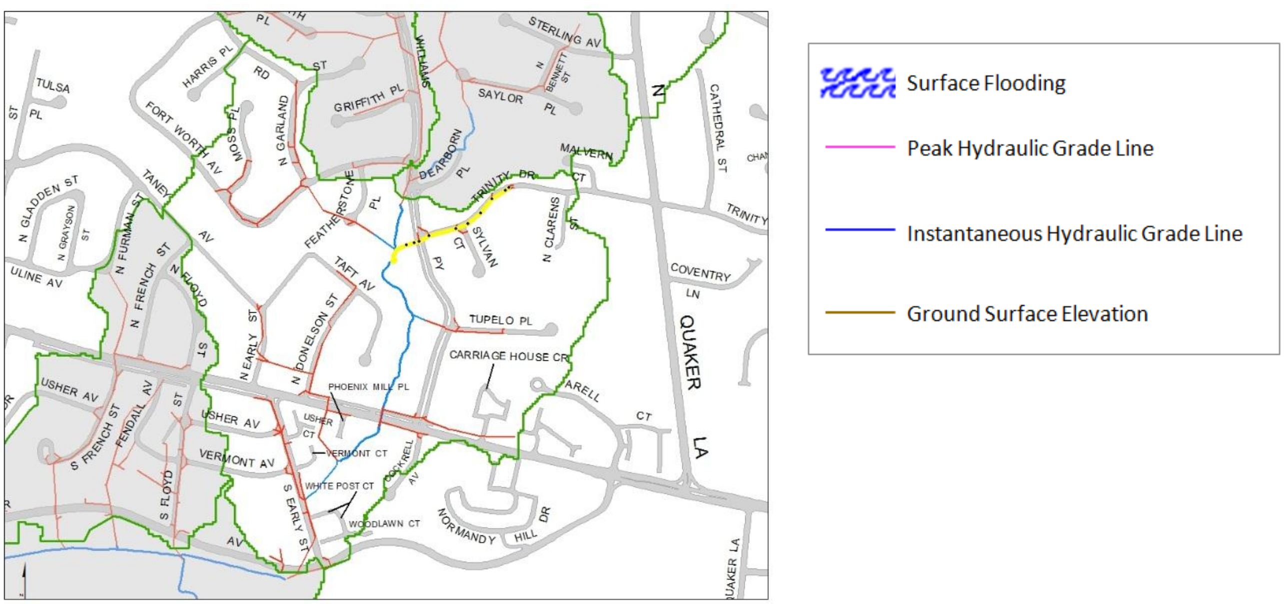
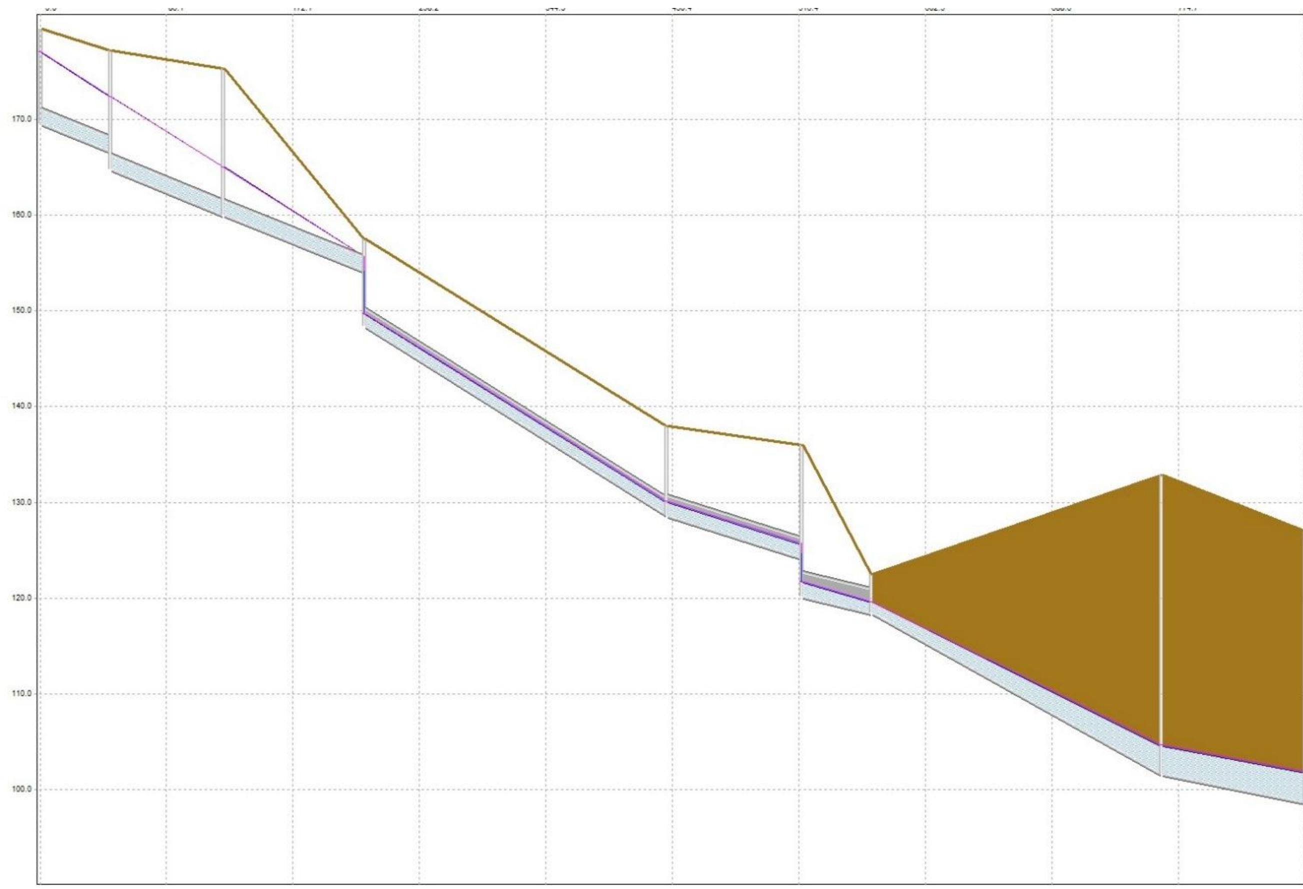


FIGURE 14

Strawberry Run Profile 14 from 001305IN to ND_0.945



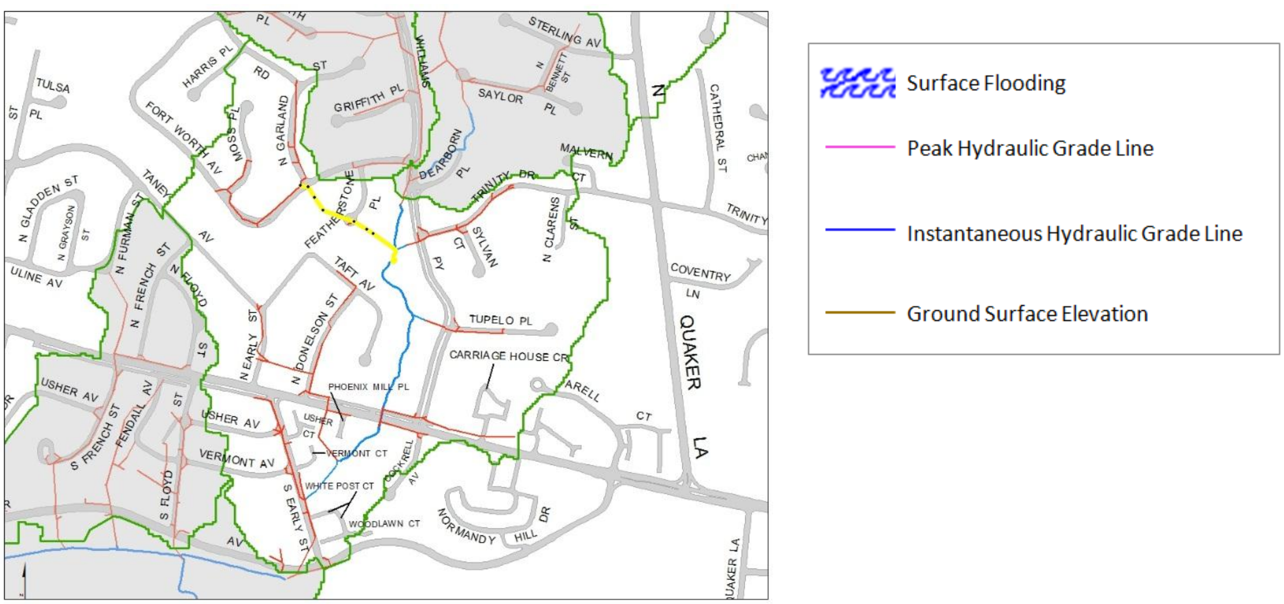


FIGURE 15

Strawberry Run Profile 15 from 001366IN to 001306IN

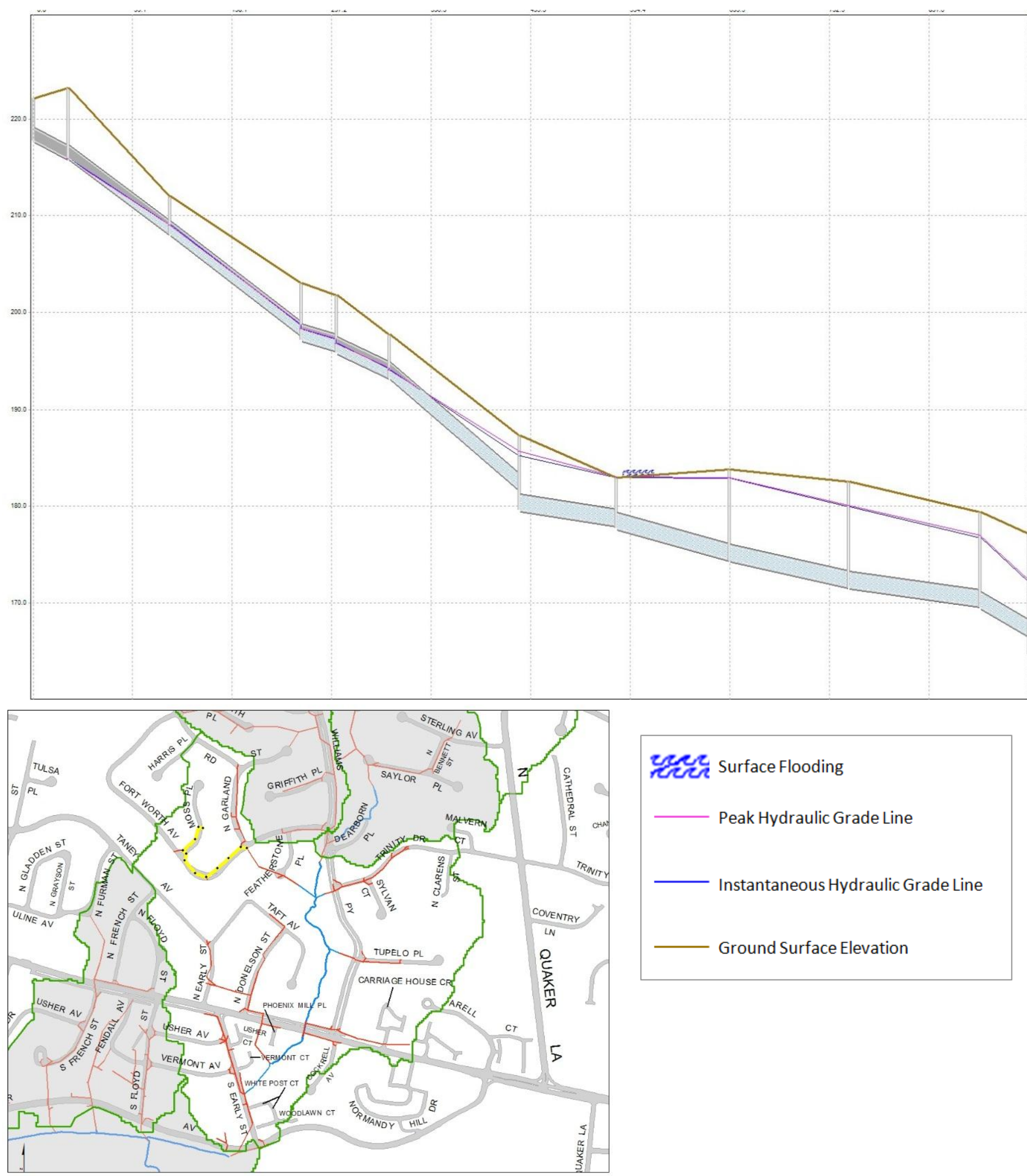


FIGURE 16

Strawberry Run Profile 16 from 001349IN to 001306IN

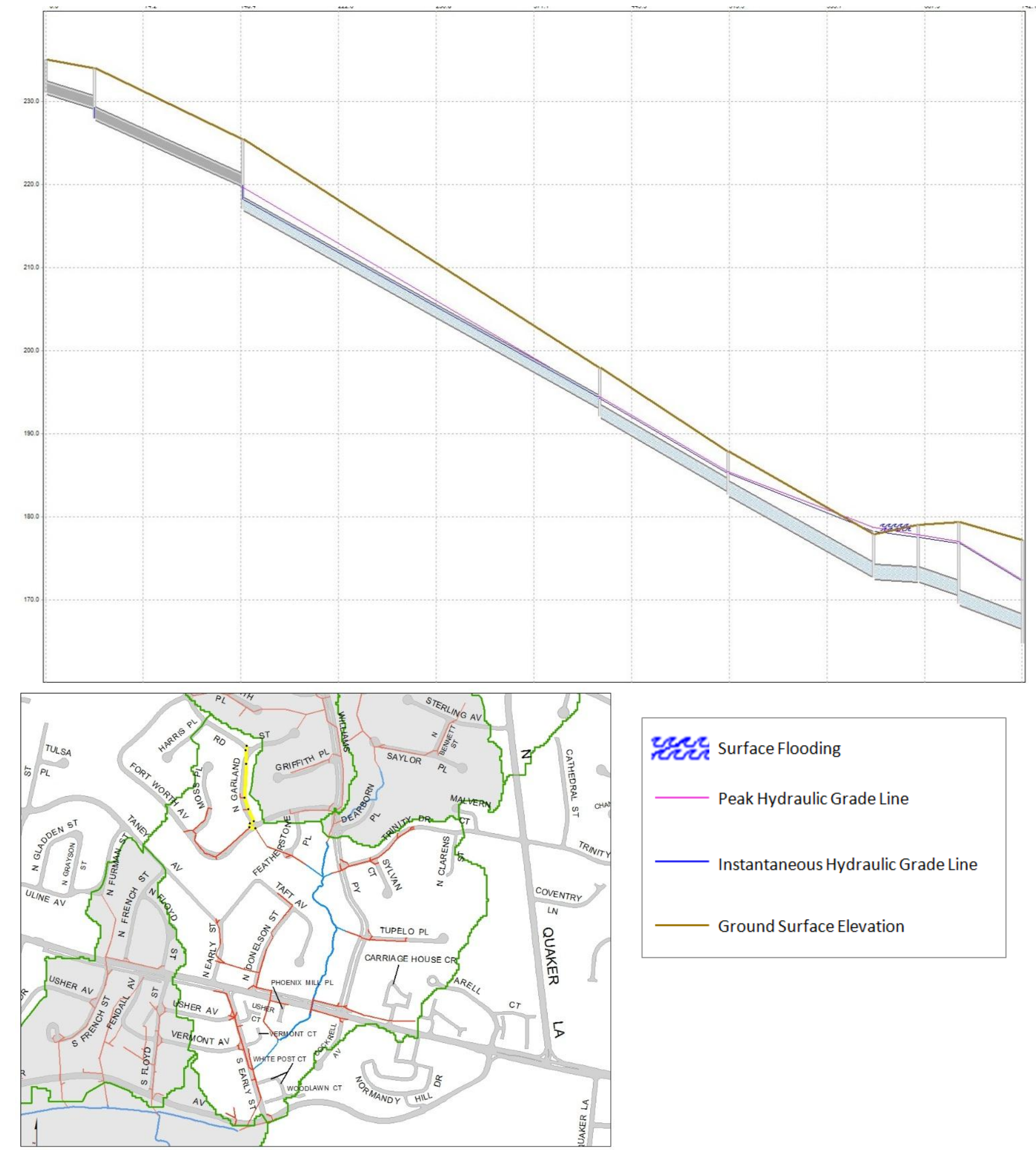


FIGURE 17

Strawberry Run Profile 17 from 002891IN to 000414SMH

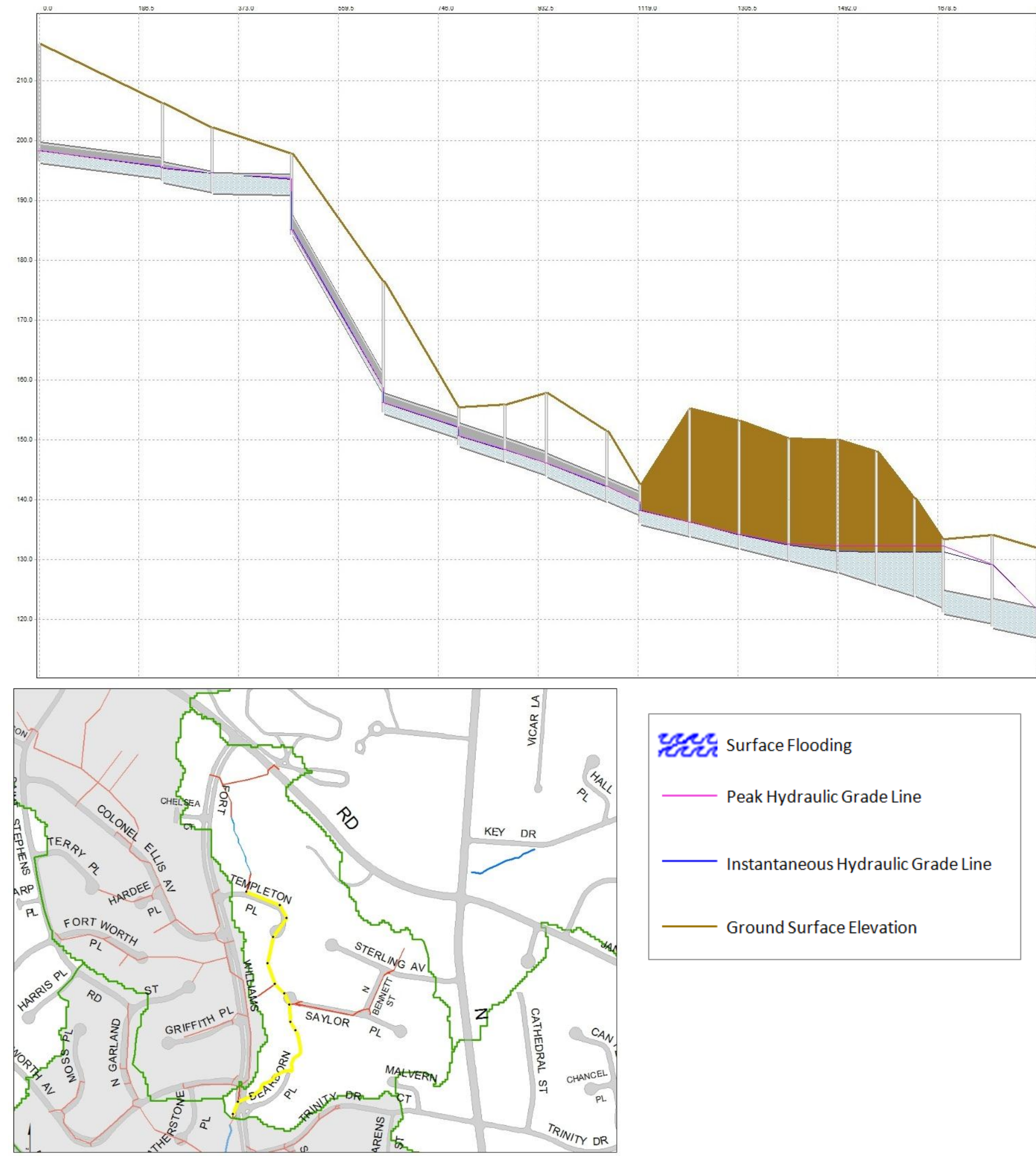


FIGURE 18

Strawberry Run Profile 18 from 001290IN to ND_1.1525

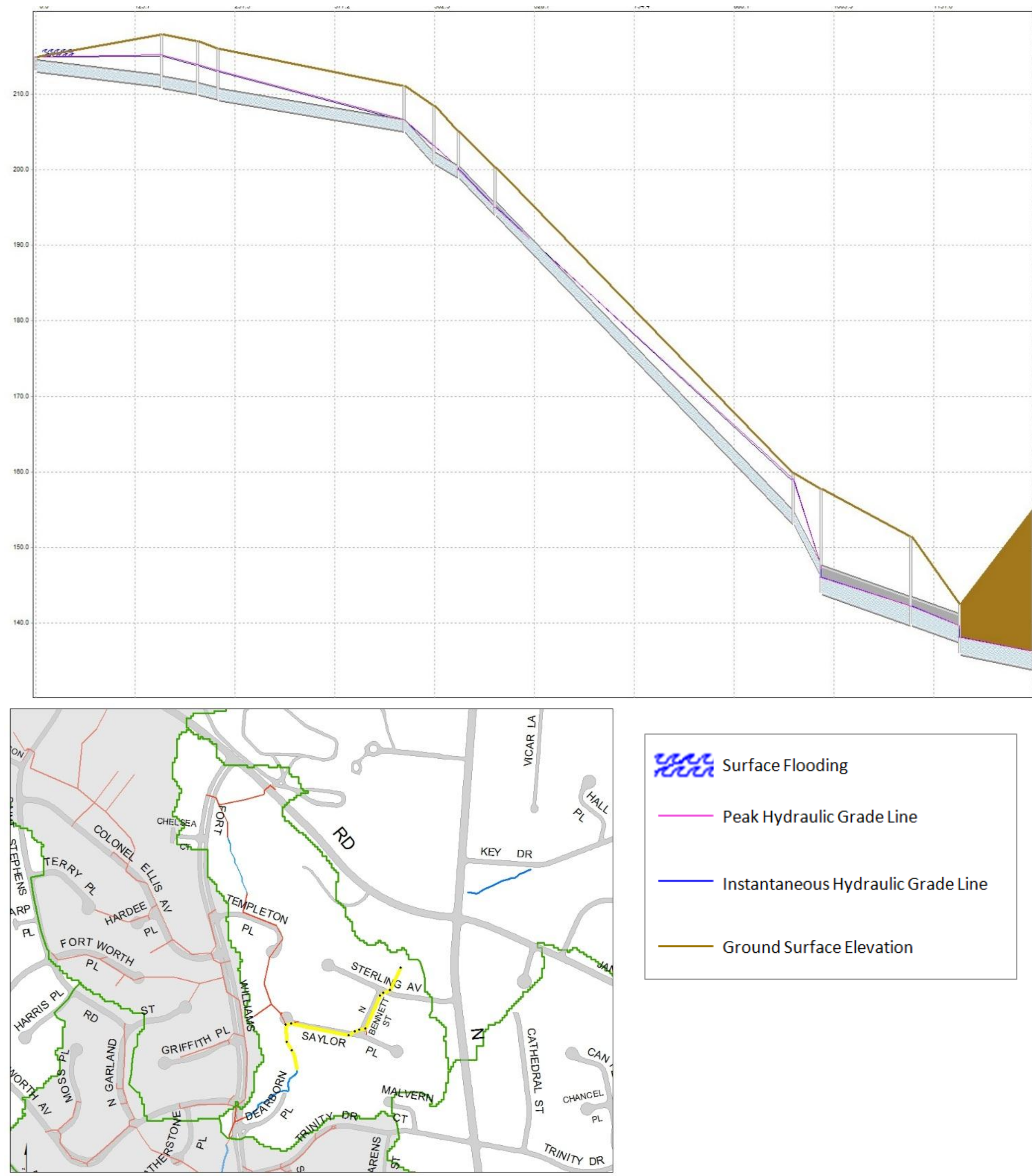
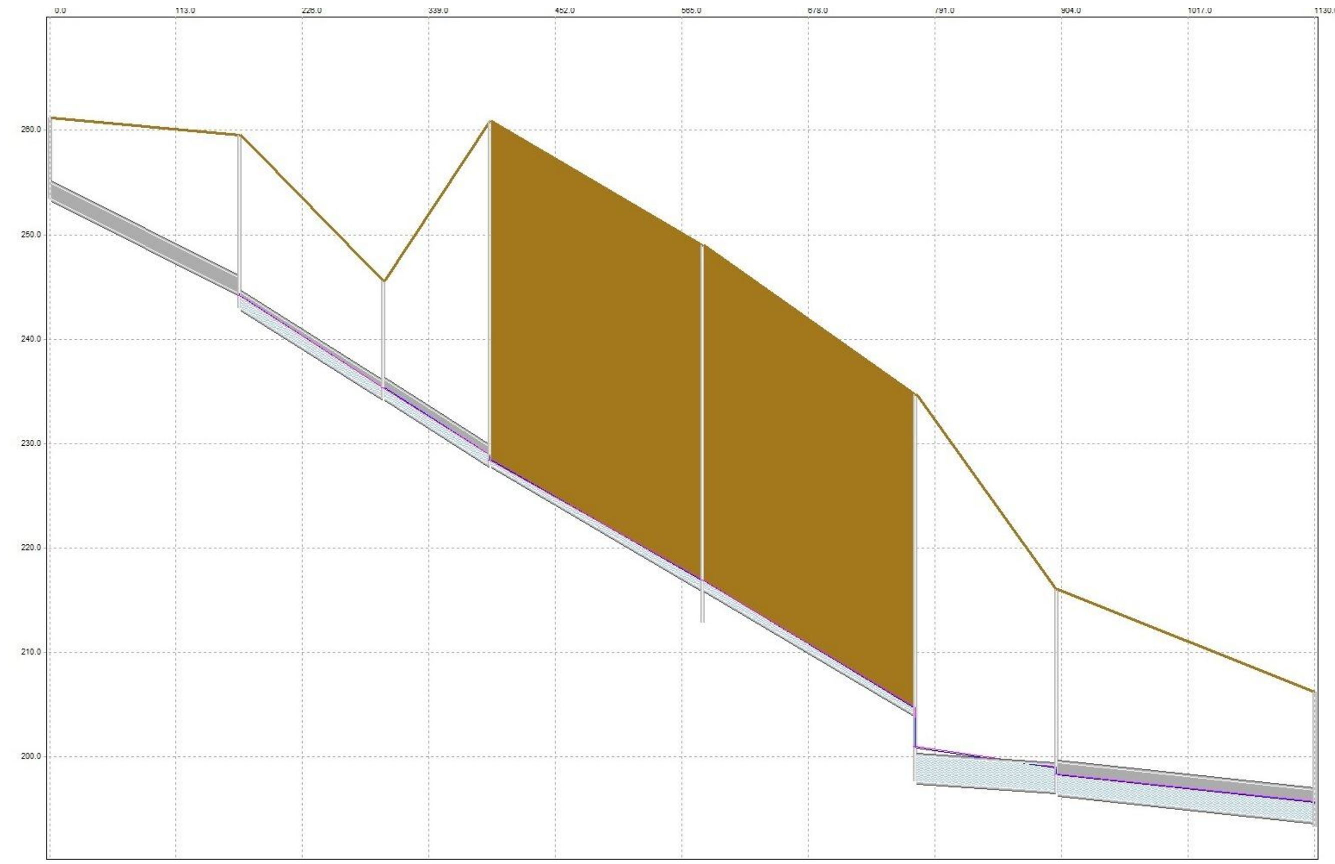


FIGURE 19

Strawberry Run Profile 19 from 000899SMH to 000432SMH



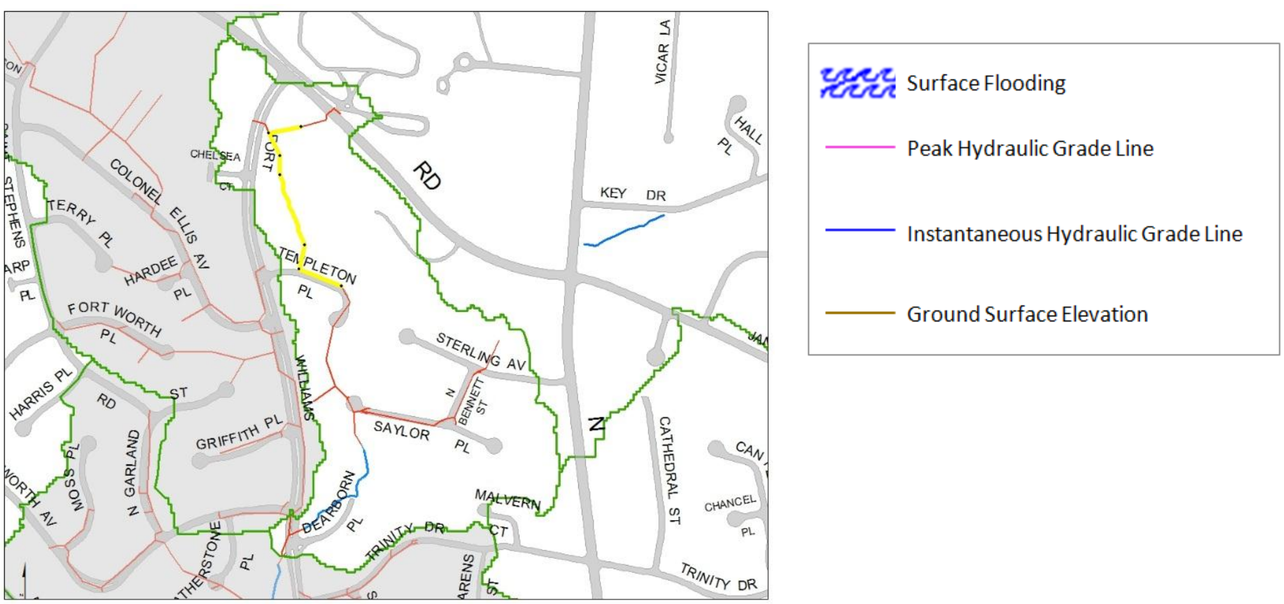
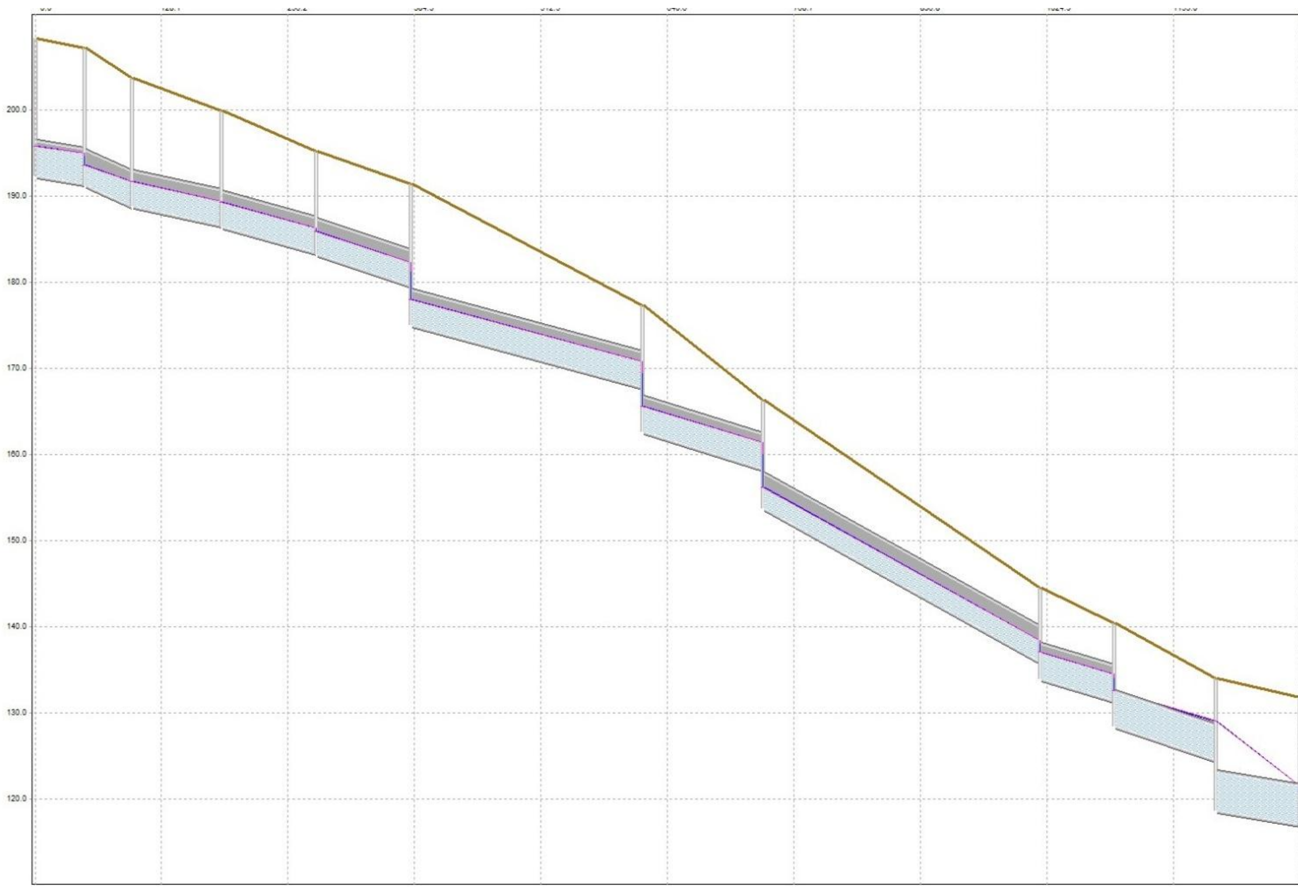


FIGURE 20

Strawberry Run Profile 20 from 001394IN to 000414SMH



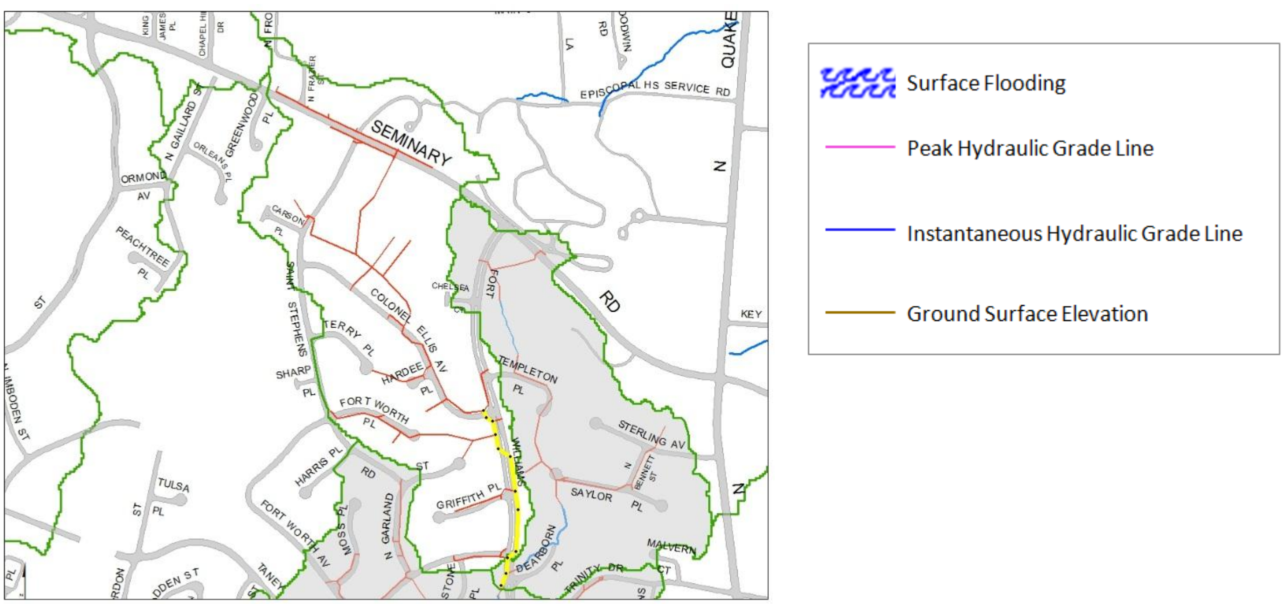
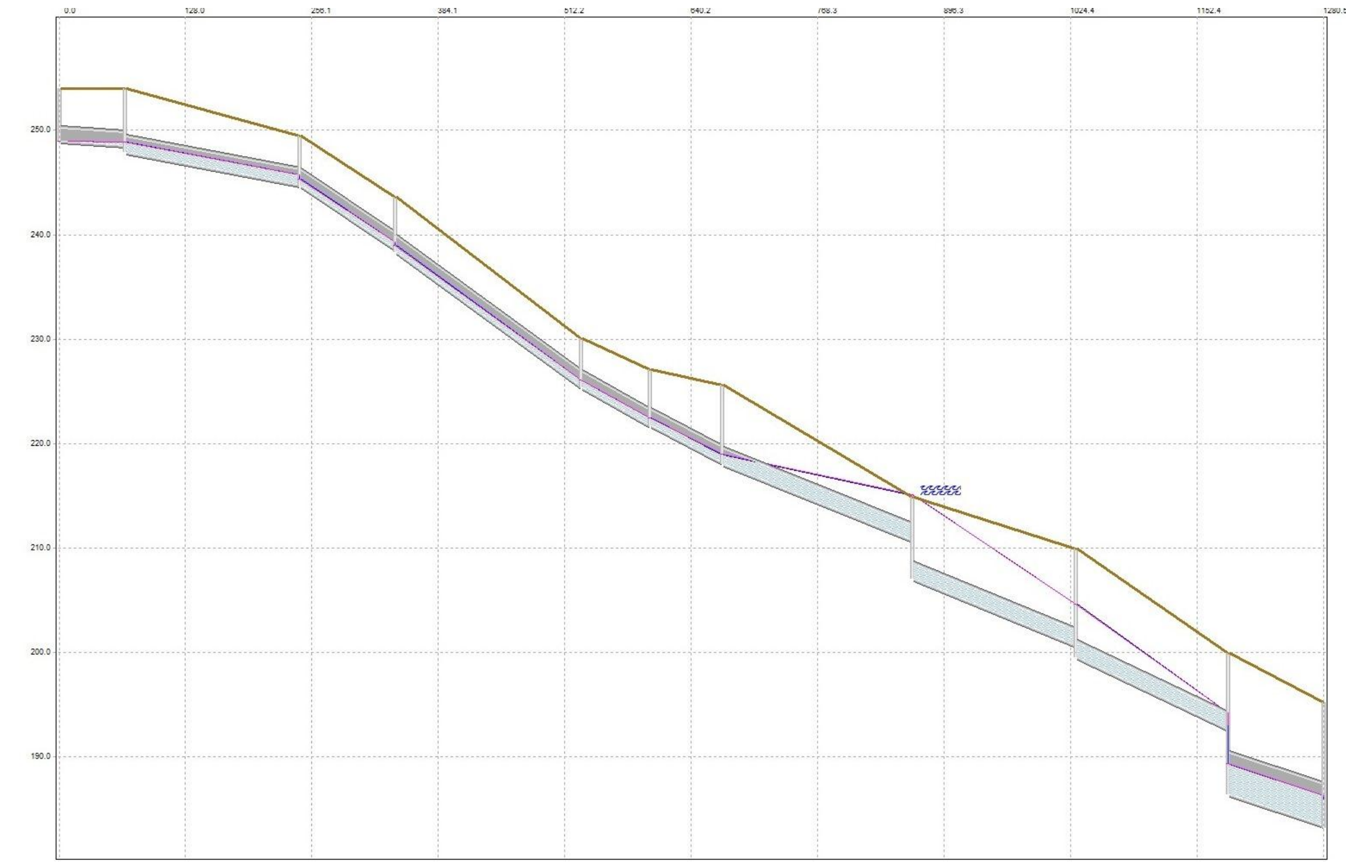


FIGURE 21

Strawberry Run Profile 21 from 001356IN to 001389IN



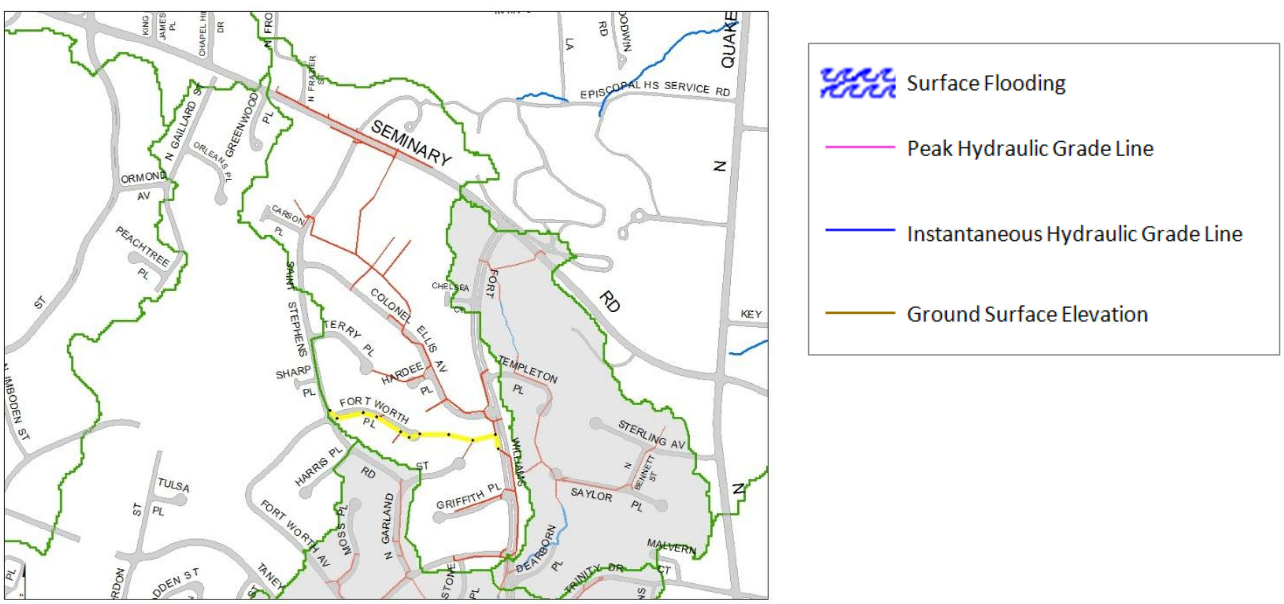


FIGURE 22

Strawberry Run Profile 22 from 002866IN to 001393IN

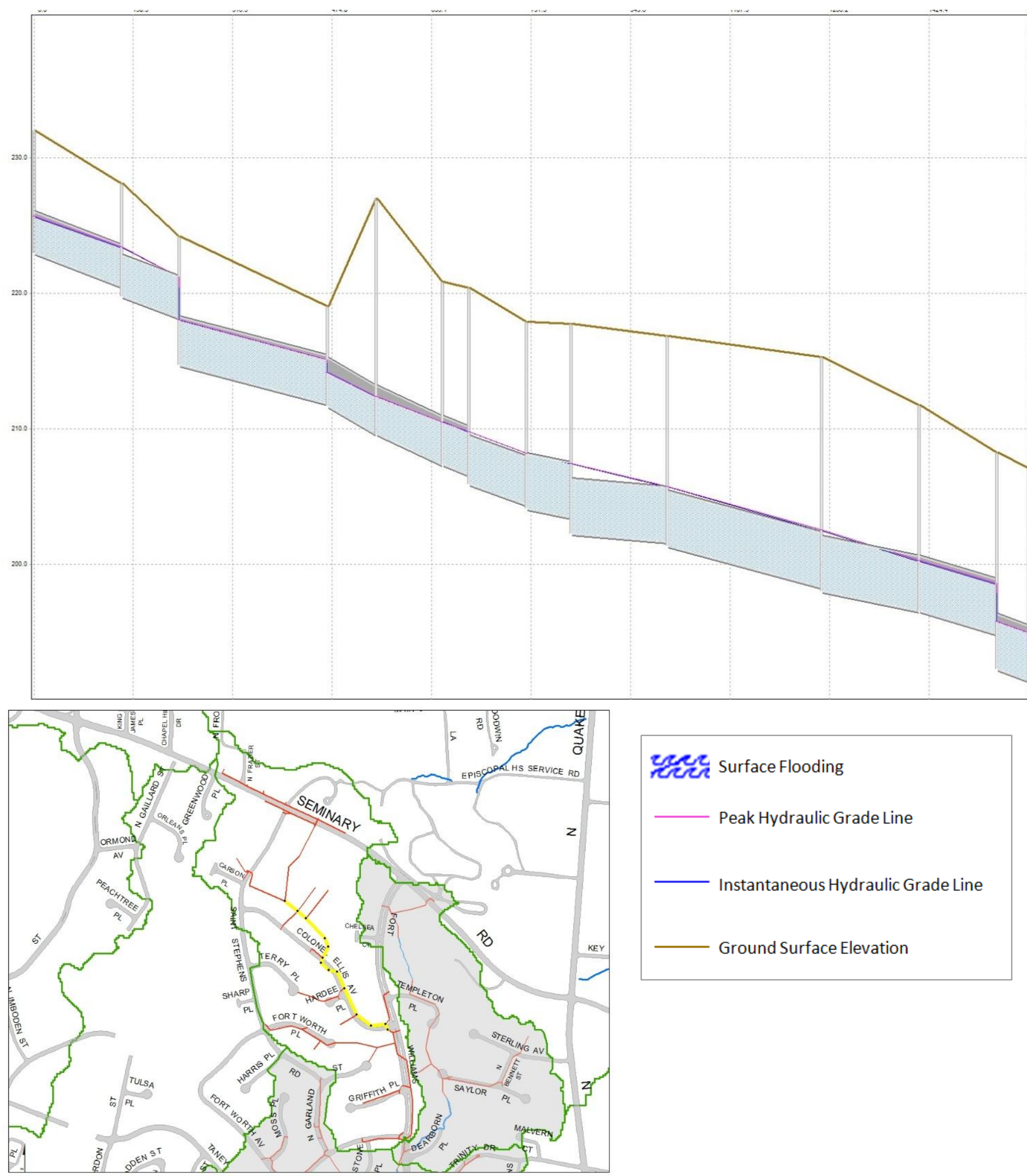


FIGURE 23

Strawberry Run Profile 23 from 001200SMH to 000891SMH